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INCORPORATION OF SHELTER INTO APARTMENTS AND OFFICE BUILDINGS

56

SUMMARY OF TECHNICAL PUBLICATIONS PROGRAM

PROTECTIVE STRUCTURES DIVISION

October, 1962

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100-2 Design & Review of Structures for Protection from Initial Nuclear Radiation

100-3 Design & Review of Structures for Protection from Initial Thermal Radiation & Fire

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80-14 Simplified Methods of Shielding Analysis

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PREFACE

This Professional Guide is one of a series of technical publications prepared under direction of the Protective Structures Division, Office of Civil Defense. The purpose of the Office of Civil Defense Technical Publications Program is to assist architects and engineers in the planning and design of structures that contain protective features.

This publication was prepared for the Department of Defense, Office of Civil Defense by Eberle M. Smith Associates, Incorporated, Architects and Engineers of Detroit, Michigan from materials developed in previous reports of fallout radiation protection in apartment and office buildings, and data compiled during the construction of shelters under the federally sponsored Prototype Shelter Program. The text of this publication has been reviewed by the American Institute of Architects and other appropriate associations and Federal agencies.

Of the design examples included, the shelter in the State Office Building, Pittsburgh, Pennsylvania was initially planned by the General Services Administration of the United States, and the shelter in the State Office Building, Albany, New York was planned by the firm of Consoer, White & Hersey, Defense Engineering Consultants, Washington, D. C. Others are by Eberle M. Smith Associates, Inc.

This publication is presented as an interim edition to meet the immediate need of architects and engineers, and to allow the professions to contribute their experience for consideration in preparation of the final version. Comments should be sent directly to the Protective Structures Division, Office of Civil Defense.

The Technical Publications Program consists of five categories:

Professional Manuals present the technology of design and review for protection against weapons effects.

Professional Guides orient this technology to the incorporation of protective features into normal use structures, such as: schools, apartment buildings, industrial plants.

Technical Memoranda present subjects, not of sufficient scope to warrant presentation as a manual or guide. These generally consist of performance requirements for shelters and shelter components.

Design Studies present, in general outline form, suggested designs for incorporating protective features into normal use structures.

Engineering Case Studies are engineering reports on the design and construction of specific projects.

Listings of publications now under preparation are included on the inside covers of this guide. Those currently available are indicated by an asterisk. Request for copies should be made on company letterhead to the Protective Structures Division, Office of Civil Defense, Washington 25, D. C., or to Regional Offices listed in Appendix C.

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CHAPTER I

INTRODUCTION

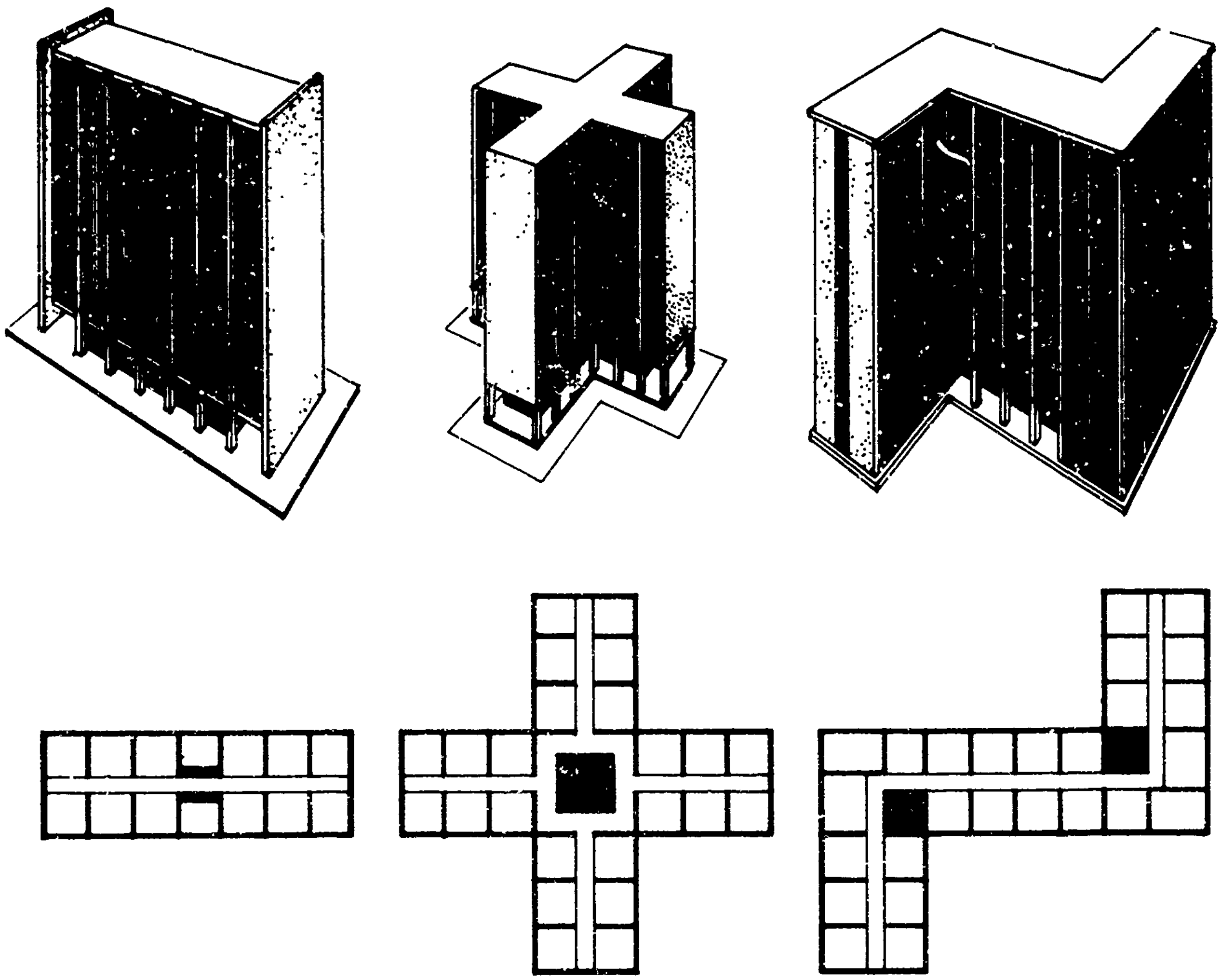
About 98% of the increase in the population of the United States in recent years has occurred in 168 major metropolitan areas, particularly in their suburban fringes. As population density has increased there has been a corresponding tendency for land values to rise and for new construction in urban areas to run to several stories in height in order to produce an adequate return on the land investment.

The two building types considered in this guide, apartment buildings and office buildings, are characteristic of urban expansion and development. On weekdays, a substantial proportion of the urban population will occupy office buildings. At other times the apartment buildings will be at maximum occupancy. Consequently, the provision of shelter in office and apartment buildings is an important contribution to the National Shelter Program.

Studies indicate that a great many urban buildings, even though they were designed with no thought of shelter, give quite adequate protection against fallout radiation for persons in the basement and, occasionally, in the corridors of upper floors. In new buildings, space designed to serve a normal use requirement can be planned for emergency use as shelter. Such shelter is ordinarily less expensive than a separate underground shelter adjacent to the building, even where sufficient unoccupied site area is available for the separate shelter. Shelter in the building is easily and well maintained in most cases, since most systems for shelter use must be kept in good operating condition for normal use. The same maintenance personnel presumably would be available to operate and service equipment during an emergency.

With few exceptions, apartment and office buildings are expected to return an income to their owners. Before proceeding with plans for a shelter, an owner would wish to consider his tax position on the capital expenditure, the additional costs of maintenance, if any, and the possible increase in valuation with respect to local property taxes. Against these should be balanced the enhancement of the physical value of the building and its ability to attract desirable tenants. As large business enterprises become increasingly concerned over the need to protect key personnel and as competition for apartment tenants becomes more acute, the availability of shelter in apartment and office buildings may help them to obtain a favorable occupancy and a higher rate of return on the total investment. In turn, business enterprises may find it easier to obtain competent clerical help if shelter facilities form a part of employee benefits.

The basic purpose of this guide is to indicate ways that shelter against nuclear attack can be incorporated economically in apartment and office buildings without detriment to their normal use. To this end it will discuss the problems that must be considered in the preliminary planning of the building and shelter, and information for the guidance of the architect/engineer in preparing working drawings and specifications. In addition, it will discuss generally some special problems which arise with regard to climate and locality, and which are treated in detail in other publications of the Office of Civil Defense. An introduction to Weapons Effects is included at Appendix A.



TYPICAL APARTMENT BUILDINGS

CHAPTER II

CHARACTERISTICS OF TYPICAL BUILDINGS AS REALTED TO SHELTER

2-1 Typical Apartment Buildings

Apartment buildings may be differentiated according to their physical structure, their ownership (public or private) or their general arrangement of space.

2-1.1 Structure

Recent apartment construction has utilized the three main types of framing: (1) Wall bearing, (2) Skeleton, and (3) Cellular, but except for "Garden Apartments" of one to three stories, almost all of it has been of skeleton construction and most of it in concrete.

Bearing walls are no longer common in apartment house construction although most codes permit their use up to seven stories. Prior to 1930 most apartment houses were constructed with wood joist floors on bearing walls which, in the lower stories, were often of solid masonry 2 feet thick. Many of these old buildings are capable of providing excellent radiation protection.

Even today most cities require 12 inches of masonry in exterior walls and few accept thin curtain wall constructions. Window sizes have increased, however, occasionally running as high as 70% of the exterior wall area. In such cases the exterior walls are of little value as a shield against fallout radiation. In the late twenties and thirties, most taller apartments were steel skeleton-framed, many with short span concrete floors. More recently, both high and low rise buildings are being skeleton-framed of concrete. Some row and terrace housing, of course, is still wood-framed, but apartment owners are finding that fire-resistant construction usually pays for itself in lowered insurance rates. So-called "cellular", or concrete box-frame construction is most economically used when the same size bays are repeated. It has the advantage of incorporating shear walls as part of the framing, capable of resisting wind load or seismic forces. Another technique used for providing resistance to horizontal loads is the judicious placement of a central vertical circulation core to provide bracing.

2-1.2 Ownership

About 85% of apartments are privately owned, the remainder being low-rent public housing. The recent trend in private apartments has been toward cooperatives, in which ownership is distributed among the tenants, with consequent tax advantages. Cooperatives typically have been conventionally financed (rather than FHA-insured), and have been designed for upper-middle income families with few children. Cooperatives are distinguished by generously sized apartment units, averaging 1200 square feet in area (about 40% larger than those in large scale rental projects).

2-1.3 Space Arrangement

Space planning in high rise apartment buildings usually begins with the elevator locations. The cost of elevators often has led planners to the X-plan in order to reduce circulation space and get the maximum number of dwelling units per elevator. This same factor has kept the height of X-plan buildings at 13 to 19 stories, a pattern which became a stereotype for public housing projects for some years following World War II. In low-rise buildings (up to six stories), Z-plans were also common.

In more recent years, seeking to improve on the poor orientation resulting from the X-plan, planners have attempted in-line schemes using distributed, rather than centralized, vertical circulation. To offset the increased number of elevators required, they have experimented with skip-floor schemes which reduce corridors and improve livability, but add interior stairways. A number of recent public projects have utilized distributed vertical circulation, but have reduced cost by using open gallery corridors. This trend away from the standard central-core, double-loaded corridor, has significance for shelter-planners. Buildings with open corridors have far less potential upper-level shelter area.

In private projects, air conditioning is nearly universal in the newer buildings. Consequently, cross-ventilation is no longer of great importance and deeper space is permissable. Air conditioning costs go up the more a building varies from a compact plan. This has led to the currently prevalent, central-core tower for private projects, a trend given impetus by the fact that higher apartments with wider views bring higher rents. Interior baths, still outlawed in a few cities, are increasingly accepted, and interior kitchens are often permitted. Such spaces are mechanically ventilated, and may be unpopular with tenants if care is not taken to prevent sound transmission between apartments through the ductwork. Interior bedrooms are generally forbidden by local ordinances. If the interior bedroom were to gain acceptance in the United States as it has in Europe, the problems of planning shelter in apartment buildings would be simplified. In any event, the trend toward square deep-space towers for private housing promises more potential above-ground protected space than the once popular X-plan.

2-1.4 Emergency Use of Facilities

Apartment building basements normally used for recreation, storage, laundry and drying rooms, or parking, offer an excellent possibility of providing satisfactory shelter. Similar facilities on upper floors may also be adapted to shelter purposes although the protection factor against fallout radiation may not be as high as that provided by basement shelter. Shelter in interior rooms and corridors of upper floors has the special advantage that bedding, food, water, medical supplies and sanitary conveniences are all available in the adjacent apartments.

Although most cities require two enclosed stairs for egress from all apartment floors, basements sometimes have but one means of exit. Basements used for shelter should have at least two exits, widely separated and protected against jamming by shock or debris.

2-1.5 Mechanical Systems

Some of the systems designed for normal operation of an apartment building may also be adequate, with minor modifications, for shelter operation if they can be kept in service. There will be little or no demand for heat in the shelter, and normal lighting levels and water supply will be more than adequate. On the other hand, the sanitary facilities near or inside the shelter may need to be supplemented and the ventilation is likely to require special consideration.

While most of the newer apartment buildings in excess of four stories have elevators, it may not be feasible or necessary to keep them in operation during an emergency.

In the majority of apartment buildings the electricity for each dwelling unit is individually metered, while circuits for stairwells, halls, basement areas and equipment rooms are distributed through "house" panels. During an emergency it might be sufficient for shelter purposes if electric service were maintained to the "house" panels alone.

Normal water use in apartment buildings is high, averaging 50 to 120 gallons per occupant per day, depending on the requirements of air-conditioning, laundries, dishwashers, lawn sprinkling and other uses in addition to personal consumption. Most buildings of any height are provided with a house pump and water storage in a house tank on the roof to insure adequate pressure in the water system. The system usually includes domestic hot water heaters and storage tanks, although instantaneous heaters are sometimes used. Buildings over 6 stories in height usually have a fire pump and a standpipe system with extra storage in the house tank as a fire reserve. The standpipes supply water to hose cabinets on each floor. Occasionally extra water storage is provided for air conditioning. Water in the various tanks and pipe systems may be an invaluable resource during an emergency.

Most apartments have a central steam or hot water heating system. Newer apartments may provide cooling by individual self-contained room units, or by a central unit with cold air ducts, or by a system which pumps refrigerant from a central location to fan units in each apartment. This last has the advantage that the same fan units can be used both for winter heating and for summer cooling.

For conventional types of heating the recommended minimum fuel supply is ten days. Such an available reserve could be of great value in the operation of a shelter, not only as a source of heat but also as a possible means of operating an emergency engine-generator for electrical power. Cooling might also be of distinct advantage in maintaining a comfortable environment in the shelter during hot, humid weather. A few apartment houses use central ventilation systems, but in most older apartment houses no mechanical ventilation is provided except in corridors, and in most newer buildings only interior bathrooms and kitchens are mechanically ventilated. Apartment basement spaces may have to be provided with mechanical ventilation for shelter use which might not otherwise be required except in the few cases where the basement is used for parking. Shelters in upper floor corridors may be able to do without mechanical ventilation if sufficient air is available from the adjacent unoccupied apartments.

2-2 Typical Office Buildings

The principal differences among office buildings relate to size; in other respects there is much less variation than among apartment buildings.

2-2.1 Structure

Framing is predominantly steel skeleton construction which is well suited to the wide column spacing and suspended ceilings (with concealed mechanical services) typical of office buildings. Where concrete skeleton construction is used, it rarely exceeds 12 stories.

Bearing wall construction has been almost unknown in office building planning since 1900, although recently several quite small office buildings (under five stories) have made use of the technique. Much more common today is the exterior curtain wall. In no other building type has the thin panel hung on the structural frame been used so extensively. Sometimes, the panels are as thin as 5/16 of an inch, or as thick as 7-3/4". Their weight may vary from two pounds per square foot, with no masonry, to forty pounds per square foot, if a full wall of masonry backup is required by fire code. The panel walls, which once were all metal and glass, are now being made in other materials including large pre-cast concrete wall sections. Brick is still the least costly finished material available to enclose a building, but it adds to total weight and its bulk reduces building floor space. Consequently, panel walls are quite competitive.

In most office buildings of the twenties, about 25% of the peripheral wall area was glass, but the amount has increased in recent years up to 75%

for the glassiest of the New York skyscrapers. The combination of curtain wall and large glass areas renders the exterior walls of many modern office buildings practically valueless as shielding against fallout radiation. Scarcely better are the light panel walls which are generally preferred for interior partitions because of the ease with which they can be relocated. Usually, only the permanent interior partitions around stairs, shafts, toilet rooms and other elements of the core are capable of giving a useful degree of radiation shielding.

2-2.2 Size

Nation-wide over the years the average population per office building has never varied greatly from 1000 persons. New York buildings run considerably higher, however, in one case as high as 15,000. Office workers constitute nearly 30% of the country's labor force (as against 16% in 1942) and more than half are women.

Since populations of most office buildings are difficult to predict and are subject to change with changes in occupancy it may be helpful for shelter planning purposes to estimate building population according to the following approximate rule proposed by American Business Magazine:

Building Population	Gross Bldg. Area Per Person
Under 350	200 Sq. Ft.
Over 500	175 Sq. Ft.

2-2.3 Space Arrangement

Economical use of space for horizontal traffic, which is a major consideration in apartment house planning, is not stressed in office buildings. In current buildings, the pattern is usually for rectangular office floors to be centered about a service core with the clear space rented to tenants who devise their own internal horizontal traffic scheme. In general, it has been found that tenants would rather walk a distance than wait for an elevator; hence, the distributed elevator schemes characteristic of much apartment building planning are not often used in offices.

Most codes require two fire stairs in office buildings higher than 3 stories and these are frequently provided in the form of overlapping "scissor" stairs where the code does not require them to be widely separated. In addition to elevators and stairs the central core usually contains pipe shafts, custodial space and washrooms. Under modern codes, mechanical ventilation is permitted for washrooms, obviating the necessity for the air shafts found in many older buildings. Instead of placing men's and women's washrooms back-to-back along a pipe space, newer designs often place the two washrooms in line, with a partition between them that can be relocated according to changes in the ratio of males to females on the floor.

Since one janitor's closet is adequate to serve an area of about 7500 square feet, most typical office floors will have at least two such closets, located on opposite sides of the core.

For many years, a cardinal principle in office planning was that rental space should not be more than 25 to 30 feet from a window. The premise was that interior space, dark and poorly ventilated, would not return its investment. Rockefeller Center stressed this idea and the resultant buildings were tall, slim slabs. In such a building complex, not originally air conditioned, this was sound planning, but in air conditioned structures deep space can be comfortable and useful. Deep space still draws slightly lower rentals, but no longer is it necessarily unprofitable to build. Formerly, only a few buildings with a high medical occupancy made a profit with deep space by using it for waiting rooms and laboratories, but several of the best new office buildings have clerical areas 45 feet deep. Some exceptional new buildings have virtually no windows at all. If this should become a trend, it would simplify the problems of planning shelter in office buildings.

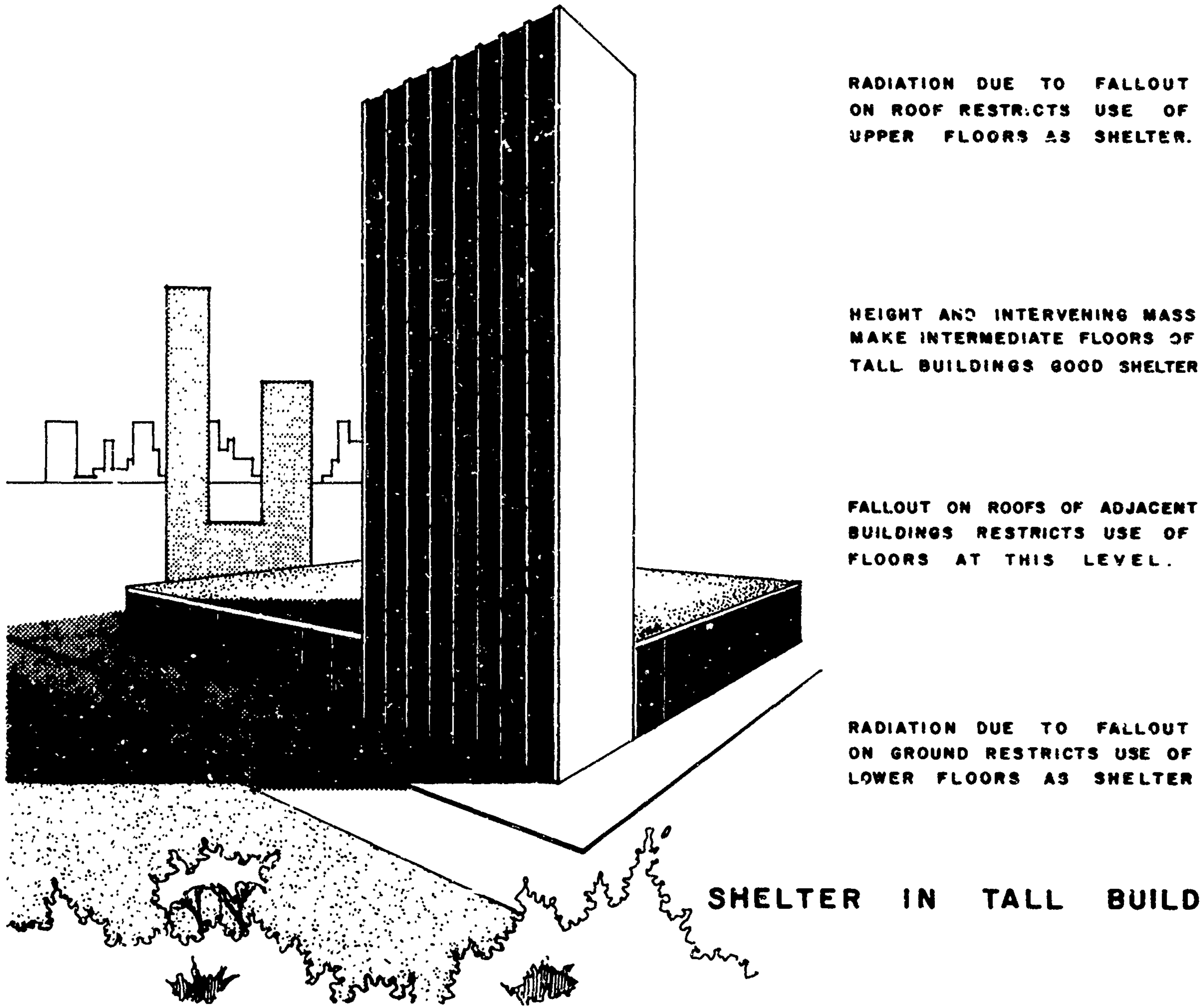
Among the conspicuous changes in office building planning over the last three decades has been the change in the use of basement space. Not only has the emphasis on tower plans sometimes reduced basement size, but the basement space itself has altered in function. Since air conditioning often is best handled by upper-story or rooftop equipment, there has been a trend away from using the basement as a major mechanical equipment space. It is now unusual to plan ground floor space in office buildings for rental to merchants; consequently basements are not required for storage of merchandise. In a few modern buildings basements have simply been omitted, but in others they are used for printing, paper storage, business machines, vaults, photographic work, employee lounges, kitchen, cafeteria, auditorium and, most recently, parking. Parking may occupy as many as four basements and ocasionally extends up to a mezzanine or second floor. If basement parking is provided on the basis of one space for every 17 occupants (an average allowance), this would amount to slightly less than 15 square feet per occupant, which is more than adequate for shelter purposes.

2-2.4 Emergency Use of Facilities

If provided with adequate exits and ventilation, office building basements offer very satisfactory shelter. One basement is usually capable of sheltering the normal population of about twelve stories under average occupancy. There is also the possibility in some cases of making use of the core spaces on upper floors for shelter. Upper floor shelter in office buildings is not as convenient as in apartment buildings, however, since all emergency bedding, food and medical supplies need to be stored in locations which will not interfere with normal office use of the building.

2-2.5 Mechanical Systems

Some of the systems designed for normal operation of an office building may also be adequate, with minor modifications, for shelter operation if they



SHELTER IN TALL BUILDINGS

can be kept in service. There will be little or no demand for heat in the shelter, and normal lighting levels and water supply will be more than adequate. On the other hand, the sanitary facilities near or inside the shelter may need to be supplemented and the ventilation is likely to require special consideration.

Climate control by mechanical means is a characteristic of most new office buildings. Mechanical ventilation systems are used not only to provide fresh air but to control heat and humidity on a year around basis. In modern buildings, the mechanical equipment needed to supply these services usually is not all located in the basement but is dispersed throughout the office building, sometimes in a central core, sometimes on upper floors, or sometimes on so-called "mechanical floors" located at regular intervals throughout the building. Mechanical ventilation systems often can be adapted to shelter purposes with minor modifications of ductwork and controls. A booster fan may be required for high efficiency filters when they are installed in the emergency air supply.

The modern office building uses 10 watts of electricity per square foot and sometimes more to provide the high levels of illumination required for office work as well as to operate the mechanical equipment necessary to maintain elevator service, air conditioning, ventilation, heating and interior communication.

Normal water use in office buildings is moderate, averaging 15 to 30 gallons per person per day. Most buildings of any height use a house pump to supply a water storage tank on the roof, thus insuring adequate pressure in the system. Buildings over 20 stories in height frequently have storage tanks at intermediate levels, each supplying water to a zone 10 to 20 stories in height. Hot water heaters and storage tanks are usually provided for each zone, although instantaneous water heaters are sometimes used instead. Buildings over 6 stories in height usually have a system of fire pumps and standpipes in parallel with the domestic water supply system and similarly zoned. Extra storage is provided in the zone tanks to serve as a fire reserve. The standpipes supply water to hose cabinets on each floor and in some buildings automatic sprinkler systems are provided over escalators and in hazardous areas. Occasionally additional water storage is provided for air conditioning. Water in the various tanks and pipe systems may be a valuable resource if it can be made available to the shelter area.

Except for spaces devoted solely to storage purposes or mechanical equipment, most typical spaces in office building basements and upper story core areas have mechanical ventilation which can be adapted for shelter purposes. Sanitary facilities are usually adequate on upper floors but may need to be supplemented with temporary toilets for basement shelter.

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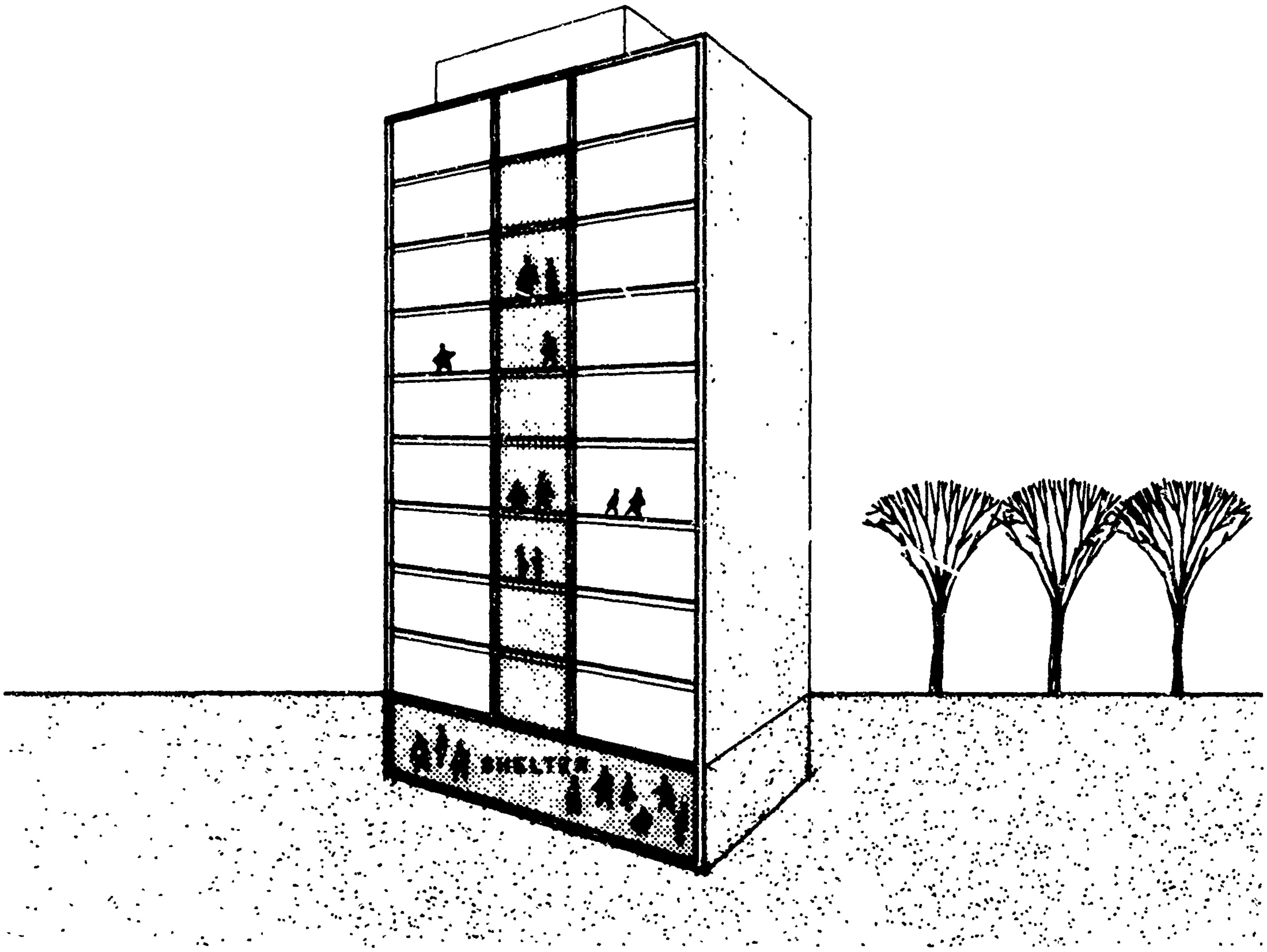
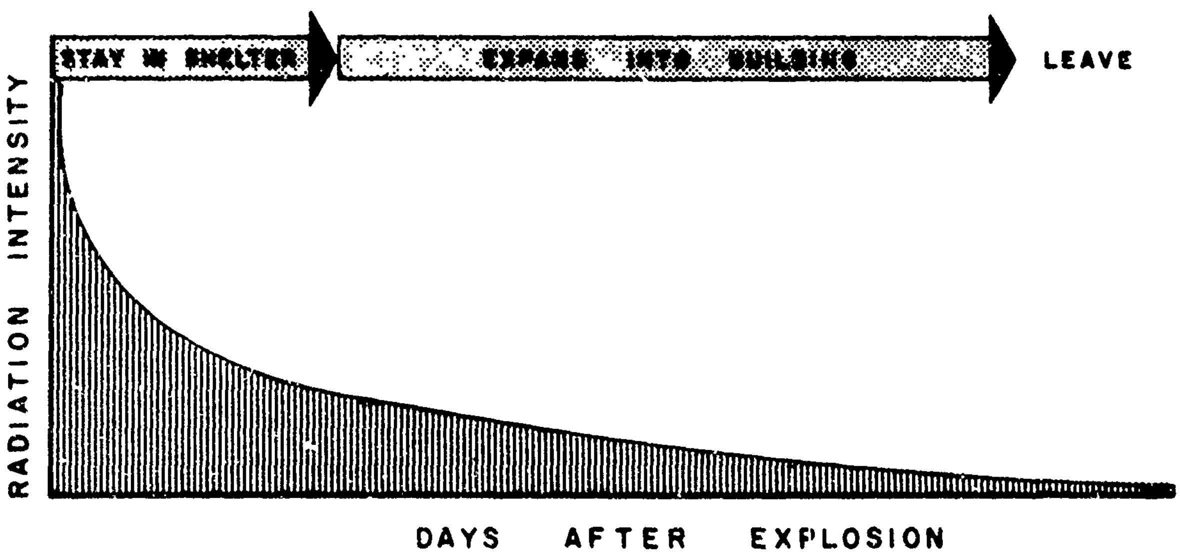

SHELTER


STAY IN SHELTER
EXPAND INTO BUILDING
LEAVE
RADIATION INTENSITY
DAYS AFTER EXPLOSION

CHAPTER III

DESIGN INFORMATION FOR SHELTER

3-1 Protection Factor

Shelter in apartment and office buildings should be shielded according to the maximum predicted intensity of radiation and, in any case, should have a protection factor of at least 100 with respect to fallout radiation. Since the effectiveness of radiation barrier materials increases exponentially with thickness, the protection factor can be improved substantially above the minimum with a relatively small increase in expense.

3-2 Blast Resistant Shelter

Where blast resistant shelter is planned in an office or apartment building, the design should also take into account the associated effects of initial nuclear radiation, thermal radiation and other fire hazards.

3-3 Net Area Per Occupant

At least 10 square feet of area per occupant is desirable for protracted periods. In many cases, however, larger numbers of people can be sheltered by crowding them into areas with high protection factors on the basis of, say, 6 square feet of net area per person during the initial period and permitting them to expand into areas with somewhat lower protection factors after the radiation hazard has decreased.

If upper floor corridors in apartment buildings were used for shelter and all sleeping were done on the floor, at least 18 square feet of net area per person would be occupied by sleepers. Even so, if enough space is available, this might be a very satisfactory way of organizing apartment shelter, since families would have access to their own living quarters and possessions and would be more self sufficient. Where space is limited, two or three tiers of temporary bunks should be erected along one side of the corridors, which are usually 3'-6" to 5'-0" wide.

In office buildings, most occupants of the shelter will be adults capable of getting along on eight hours of sleep. Under these circumstances it would be possible to establish centralized dormitory spaces operating on the basis of three shifts per day. This is a highly efficient system, but may present problems of control, since disturbances on the part of a few people could affect the portion of the shelter population which happened to be in the sleeping area.

Bunks approximately 2'-1" x 6'-4" will accommodate adults. For maximum utilization of space, bunks should be placed side by side in as many tiers as the ceiling height permits and should be entered from one end. Space requirements per sleeper, including aisles, may be estimated as follows:

2 tiers	9 square feet
3 tiers	6 square feet

At least 9 feet of ceiling height is recommended where 3-tier bunks are used, with surface mounted light fixtures. (Recessed fixtures are preferable in shelters.)

Where food service can be organized on a cafeteria basis, about 9 square feet per diner should be an adequate dining space.

If one-third of the shelter population is sleeping in 3-tier bunks and another third is eating in the "cafeteria" the remaining third will have about 15 square feet of area per person for recreational activity.

From 1 to 2 cubic feet of storage area should be allowed in addition to net area, to accommodate food, water, bunks, medical supplies and portable equipment.

If located conveniently, normal use toilets may be adequate for the shelter, provided there is adequate water for flushing and the waste disposal system can be kept in operation. Otherwise, emergency toilets should be provided to raise the total number available to about one for each twenty-five occupants. Emergency toilets may be chemical, disposable or an austere trough type with flushing provisions.

Since the fresh air filters may tend to accumulate contaminated particles during the period of fallout, they should be placed in a space which is either well shielded or is remote from the shelter area. Some shelters will require additional mechanical space to accommodate an engine-generator for emergency electrical power or a sewage ejector for emergency waste disposal. Air supplied to the engine-generator room for cooling purposes should be filtered.

Whether it will be more desirable to group shelter spaces in a single area rather than to have a number of smaller shelters at various locations throughout the apartment or office building depends primarily on the space organization of the building and the ease and economy with which the basement or other spaces on intermediate floor levels can be developed as shelter. Communications and feeding problems are minimized under an arrangement where shelter space is grouped within a single area, and there are likely to be other benefits, such as a simpler, more economical mechanical system and a reduction in the number of openings required for access and for air intake and exhaust.

On the other hand, smaller groups in dispersed shelter spaces throughout an apartment or office building may be more manageable, especially when they are based on existing family or office organization. The level of morale may be enhanced where familiar patterns of human contact are maintained. If a basement area is used for shelter space, it will simplify administrative problems if the shelter space can be planned so that various activities, such as sleeping, eating and active recreation, can be carried on in separate areas.

3-4 Ventilation

Natural ventilation may be sufficient for shelter on upper floors. Basements used as large group shelters will usually require some means of mechanical ventilation during an emergency. If the emergency ventilation system is planned to furnish at least 3 CFM of fresh air to every person in the shelter, the carbon dioxide content in the air will not exceed 0.5 percent by volume and should not prove harmful even to active persons. The oxygen content will be ample under these conditions.

Another function of the ventilation system is to maintain temperature and humidity below the point where a sedentary human body generates more heat than can be lost by convection, radiation and evaporation, with a consequent rise in body temperature. The threshold of this condition is in the neighborhood of 85 degrees effective temperature, a term used to describe any combination of temperature and relative humidity giving the same feeling of comfort (or discomfort) as 85 degrees F. at 100 percent relative humidity, under the "still" air conditions prevalent in shelters.

Where it is desired to make provision for future installation of filters for chemical and biological warfare agents, a booster fan or some other means of overcoming the additional static resistance of these filters should be considered. Keeping the shelter under a slight positive pressure, in the order of 1/4 inch of water, will help prevent the infiltration of air-borne toxic agents of this type or of combustion gases from outside conflagrations.

In hot and humid climates, where apartment and office buildings normally have equipment for cooling and dehumidifying the normal air supply, this equipment will usually be adequate to condition the emergency air supply and should be adaptable for this purpose. Where mechanical cooling alone is provided, it may be necessary in some cases to increase the rate of ventilation with outside air to help control high relative humidities within the shelter and to reduce condensation on interior surfaces which are below the dew point temperature. Calculations for cooling requirements should take into account the conductive cooling effect of the surrounding earth when the shelter or intake duct is below ground.

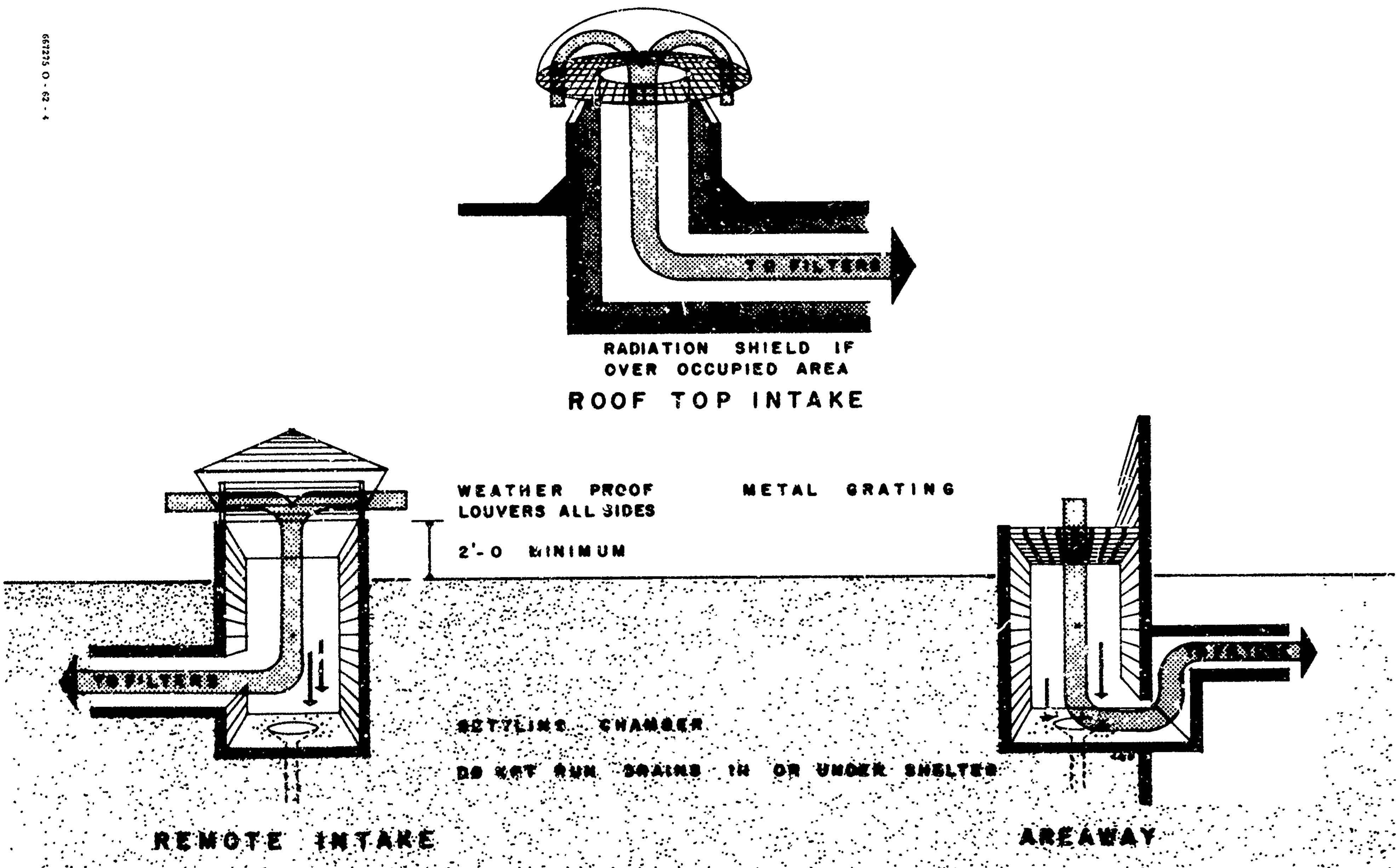
The principal modifications to a normal ventilation system to adapt it to shelter use are in the intake and filter arrangements. The intake should be screened and weather-proofed and should be placed in a location where it is not likely to be choked by debris or invaded by products of combustion.

A large percentage of fallout particles can be prevented from entering with the air stream by placing intake openings at least 2 feet above any surface (including snow) that might collect fallout, and by designing the intake so that the air turns through at least 90 degrees and enters in an upward direction at a low velocity. A system of baffles and settling chamber in the intake duct is also a feasible method of excluding large fallout particles from the air supply. In any case fresh air filters are essential, preferably located at the intake fixture. If filters are located within the building, shielding walls are required between the filter room and any occupied shelter space to protect the occupants from radiation due to contaminated material collected by the filters. It may be prudent to consider, in the original design of the fresh air system, location and space requirements for future installation of filters against chemical or biological warfare agents.

Filtered fresh air supplied to a shelter may vary from a minimum in winter to 100% in summer, with corresponding variations in the amount of recirculated air. Fresh air fans and recirculating air fans should have the capacity and flexibility to adjust to these different requirements. Although positive displacement rotary blowers have a more constant delivery under varying static pressures, cost considerations usually favor the use of centrifugal fans. The quantity of air delivered by a centrifugal fan at a given speed decreases as the system resistance increases, but this effect can be corrected by means of variable inlet vanes, adjustable dampers or a multi-speed drive.

In both apartment and office buildings separate exhaust fans are usually provided in areas which are sources of moisture, odors and other air-borne nuisances. These areas may include parking garages, kitchens, sculleries, cafeterias, employees' lounges, toilet rooms, janitor's closets and maintenance shops among others. In order to keep the shelter under positive air pressure and to direct the air flow it may be necessary to close some of the exhaust dampers and to stop the exhaust fans. An ideal arrangement would be to supply air to sleeping and general activity spaces under sufficient pressure so that it will exhaust successively through kitchen, toilet rooms and (in some cases) the engine-generator room to the outside.

If no reliable source of power is available, some provision should be made for manual operation of the ventilation system. In a large shelter, manual drive may not be feasible unless filters and other sources of flow resistance are by-passed.



FRESH AIR INTAKES

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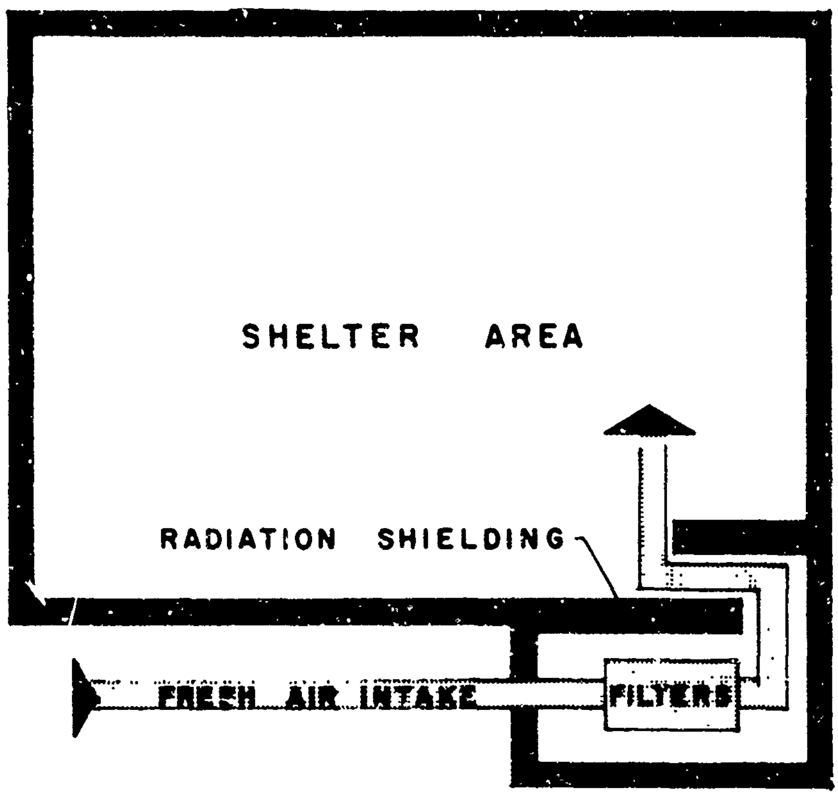

FILTER ROOM SHIELDING

3-5 Water Supply

Water should be supplied to the shelter in as generous quantities as the situation permits. At least 3-1/2 gallons per person of drinking water is required. Additional water supply will be useful for personal cleanliness, preparation of food, cleaning utensils, removal of wastes, cooling an engine-generator, cooling the air supply and emergency fire-fighting.

The water requirements for these various uses are not necessarily cumulative, since water used for cooling and dehumidifying the shelter may subsequently be used for engine cooling, personal hygiene, and ultimately, waste disposal. If the public water supply is drawn from wells, there is little danger of contamination from radioactive particles. If, however, water is stored in reservoirs, exposed surfaces may be contaminated. Soluble contaminants are not likely to be present in large concentrations. Although particle contaminants can be removed by filters and soluble contaminates can be precipitated out, removal procedures are more practicable at the water plant itself than in the shelter.

If it is determined that while the public water supply is likely to continue, it is also likely to be contaminated, contamination will not preclude the use of such water for waste disposal, heating or cooling.

Where installation of a well is not feasible or not economically justifiable, and where the normal water supply cannot be relied upon, the supply of drinking water inside the shelter should be assured either by means of a storage tank or by storage in sealed, shatter-proof containers. Water in a storage tank can be kept fresh by placing the tank in series with the normal water supply and making provisions for valving it off during emergencies.

3-6 Food

Although prepacked food rations are likely to be the main source of food supply, it may be possible to supplement them, at least at first, from normal use supplies from individual kitchens of an apartment house or from the cafeteria of an office building.

There would be psychological advantages to retaining a semblance of familiarity in the diet. A three-meal-a-day schedule should be retained, if possible, with some foods and beverages heated on hot plates. Occasionally it may even be possible to keep some food refrigerators and freezers in operation. If the shelter operated on shifts, food service might be practically continuous.

3-7 Noise Control

Noise is an important factor in fatigue, and since a shelter is apt to be crowded and uncomfortable at best, it is well worth while to take advantage of any opportunities to reduce noise levels. It will help if quiet and noisy activities can be carried on in separated spaces. Emergency mechanical equipment, especially a diesel engine-generator, should be provided with vibration isolators and placed in locations where it will cause the least discomfort. A somewhat noisy ventilating duct system may not be a disadvantage, however, since the air noise will tend to smooth out more distracting sounds.

3-8 Health

Shelter occupants are expected to suffer only transient effects from even a protracted period in the shelter, if reasonable provisions are made for disposal of wastes, personal cleanliness, disease control and first aid.

If normal sanitation practices are not feasible, wastes should be deposited in sealed containers and should be removed from the shelter as soon as it is safe to do so. Paper and burnable rubbish should not be allowed to accumulate because of the possible fire hazard.

Personal cleanliness can be accomplished by sponge bathing from portable wash basins in order to conserve water.

Although most persons in shelters would be in normal health, a few may have chronic diseases or a particular susceptibility to disease. Others may have been exposed to an infection prior to entering the shelter. The presence of young children in apartment shelters will increase the incidence of colds and other contagious diseases, and the spread of infection will be aggravated by the crowded conditions of shelter occupancy. A space should be designated for isolation and bed rest capable of accommodating perhaps 5 percent of the shelter population. Ideally, this space should have its own toilet and sink, a locked storage cabinet for sickroom supplies and a hot plate for sterilization of equipment.

Because of limitations of staff and equipment, serious cases of physical or mental illness will receive little diagnostic or therapeutic care. However, possible ill effects can be minimized by advance planning and preparation. Individuals who are to be responsible for the administration of the shelter would be well advised to take the basic National Red Cross First Aid Course and perhaps the Red Cross Home Nursing Course called "Care of the Sick and Injured." Further, the occupants of the building should be surveyed to determine if any suffer from chronic diseases requiring continuing medication or special care, such as diabetes or heart disease. Arrangements should be made with these individuals and their physicians to ensure that the disease can be given proper treatment during the period in the shelter.

3-9 Mental Health

Overcrowding, heat, humidity and rationing of food and water taken in the context of the general monotony of shelter life may aggravate basic emotional instabilities in some individuals. This will probably be more true of adults than children as under emergency stress children tend to have more psychological resilience than their elders. Most people respond more favorably to unusual situations if they are able to meet them in reasonably familiar social and physical environments.

Consequently, shelter space arrangements should provide continuity of group relationships, rather than adding disruptive influences by breaking up familiar groups. In addition, wherever possible, food and sleeping arrangements should approximate normal conditions.

Despite all precautions, however, it is wise to anticipate the possibility of major emotional upsets and behavior problems on the part of one or more persons. Should such an upset occur, some means of control or confinement will be necessary to avoid demoralizing effects upon others in the shelter.

3-10 Fire Safety

Fire prevention inside a shelter is primarily a matter of good housekeeping and common sense. The structure may be incombustible, but if paper and trash are allowed to accumulate, they can easily be ignited and can quickly produce enough heat and smoke to drive people outside.

Inflammable liquids or open flame devices should not be permitted in the shelter for cooking or any other purposes. Not only is an open flame a possible fire hazard, but also, if combustion is not complete, it is a source of carbon monoxide.

Since it will seldom be possible to enforce an effective ban on smoking in the shelter, it should be limited to a safe, well supervised and ventilated area.

Where apartment and office buildings are provided with standpipe systems, hose cabinets should be located in the shelter area. Portable fire extinguishers have the disadvantage that, once discharged, they cannot be recharged in the shelter. One or more pump-type water extinguishers with refillable tanks may be useful. Carbon dioxide extinguishers or other types which tend to make the air unbreathable have no place in a shelter. Where buildings are provided with a sprinkler system, it would be advantageous to extend the system to protect the shelter area.

3-11 Administration

Some space should be set aside for the exclusive use of the administrative staff. An outside telephone should be located here as well as a Conelrad receiver and any other communication facilities such as a house telephone, or a public address system. Radiation monitoring devices could be stored here, as well as technical manuals, equipment lists, spare parts and a logbook. The administrative area should be located, preferably, where it will have visual control over the principal shelter area.

While upper story shelters will usually house smaller, more easily controlled groups, the distances from the central administrative center will increase the problems of coordination. Under such circumstances, there should be a sub-center for administration on each floor with direct communication to the central administrative center.

Shelter operations fall into two categories: technical and administrative. The technical requirements of equipment maintenance and operation and sanitation can probably best be handled by the building's own maintenance personnel.

The administrative functions require individuals of considerably more background and training. In addition to supervising the general technical services required, administrative personnel must also be responsible for assignment of space and duties, food service, medical care, communications, census, inventory, security and morale.

If all shelter is in a single concentrated area, such as the basement, a single management team will be sufficient. If intermediate floor levels are used for shelter some system of floor management must be set up. The floor management might reasonably be drawn from the tenants of that particular floor. The responsibilities of floor management would be principally those of communications, security and morale.

Communication is essential between the upper floors and the administrative center, in order to maintain schedule, transmit information and mobilize to meet local emergencies, such as fire. If neither a house phone or a public address system is available, a temporary telephone system could be strung up through the stairways. If possible, all shelter floors should be provided with Conelrad receivers.

Some provisions should be made for the storage of recreational facilities. Books, games and arts and crafts materials should be selected as appropriate to the character, age groups, and intellectual interests of the shelter occupants.

Problems of shelter management will be minimized if the management group prepares a detailed plan for placing the shelter in operation and conducting its activities day by day, and ensures that every occupant of the building understands both the plan and his own individual responsibilities.

CHAPTER IV

APPLICATION OF DESIGN INFORMATION

4-1 Existing Buildings

Nearly all basement space in existing multi-story buildings offers good protection against fallout radiation. The principal problems in adapting these basements for shelter purposes are usually those of access and ventilation.

In addition, there may be spaces on upper floors which have sufficient distance and shielding between them and the fallout on adjacent roofs and ground to give an adequate protection factor. Access and ventilation will usually be adequate in these spaces.

If mechanical spaces are used for shelter, they should be checked to be sure that exits are adequate and that any steam or gas mains in the area are properly housed to minimize danger from possible rupture. Storage rooms should not be designated as shelter unless a plan can be devised for clearing them quickly of stored materials.

In some cases it may be desirable to furnish the shelter area with an internal system of bracing to support additional shielding material or to give the structure improved resistance to blast and debris loads. Where it is necessary to support such loads, it is best to locate the shelter in a portion of the building which is structurally compact; that is, with closely spaced columns and walls and not more than average ceiling heights.

In existing buildings it may be useful to consider a two-stage or graduated shelter; that is, the use of one space with a relatively high protection factor into which the occupants can be crowded at, say, 6 square feet of net area per person during the initial shelter period, followed by expansion into more comfortable but less protected areas of the building when the radiation hazard has diminished. As an example, shelter on upper floors can thus serve as expansion space for a basement shelter.

4-2 New Designs

When the concept of shelter is included in the preliminary planning of an apartment building or office building it becomes possible to provide better organized shelter for more people at lower unit costs as compared with shelter in existing buildings or separate fallout shelters.

Since basement shelter is usually the most economical, the building should be planned, where possible, with as much basement space as can be used effectively under normal conditions. In apartment buildings, basement space for recreation, group use, laundry and drying rooms and parking can be more easily adapted to shelter than can tenant or building storage areas.

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In office buildings, basement shelter could most easily be developed in spaces used for employee lounges, cafeteria, auditorium and parking.

So far as shelter on upper floors is concerned, the planning approach is somewhat inhibited by the fact that these floors, in apartment buildings and office buildings, are the ones which must attract tenants if the building is to earn its way. The obvious expedient of increasing the mass of the exterior walls and reducing the area of windows, which would improve both the shielding and air-conditioning aspects of the building, is not likely to be adopted as long as it is inconsistent with what most tenants like and expect. On the other hand, certain areas on upper floors can be planned to provide shelter in such a way that few tenants will even be aware of the differences.

In apartment buildings this may be accomplished by increasing the mass of the partitions enclosing interior spaces such as kitchens, toilets, corridors, stairways and store rooms and by developing the plan in such a way that openings through this partition are offset or provided with baffles against direct entry by radiation from outside. In office buildings it may be accomplished by planning the elements of the central core (elevators, stairs, toilet rooms, custodial space, mechanical space, storage and circulation space), so as to provide a sheltered area on each floor. In either case the structure can be designed to develop a degree of resistance to blast and debris loads.

Ventilation, water supply and electrical distribution and sanitary systems can be planned for ease of operation and control during an emergency. Emergency lines of communication between separate shelter areas can be provided. Access can be planned for the maximum rate of entry consistent with proper protection of openings. These items require thorough understanding of the problem and a considerable degree of design ingenuity and proficiency, but may involve very little in the way of additional cost.

4-3 Points to Check

In planning shelter in apartment and office buildings check to be sure:

1. Full advantage has been taken of all area that could be used as shelter.

2. Exits are adequate both for normal and emergency use. Door swings should be correct for normal use.

3. Outside utilities have been evaluated as to probability of service being maintained during emergencies.

4. Water stored in the building is available to shelter areas.

5. Fresh air intake is properly designed to eliminate large particles and is located where it is not likely to be affected by debris or fire.

6. Adequate shielding is provided between shelter areas and the space containing the fresh air filters.

7. Where an emergency generator has been provided, adequate filtered air is supplied to the generator room.

8. Where additional filters are used for emergency fresh air supply, provision has been made to balance the increased static head in the ventilation system.

9. Where feasible, the ventilation system has been designed to keep shelter areas under positive pressure.

10. Fuel storage tanks and supply lines are safely located.

CHAPTER V

SPECIAL PROBLEMS

5-1 Interruption of Essential Utilities

Few apartment and office buildings have their own wells and sewage disposal systems. They depend almost entirely on public utilities for these services, as well as for electric power. These services will be adequate for shelter requirements provided they can be maintained during the emergency period.

In order for power, water supply and sewage disposal plants to function during the emergency period, essential operating personnel must be provided with shelter, and the plant must be so situated and constructed as to survive nuclear attack without critical damage. These requirements are much easier to meet for conventional water supply and sewage disposal plants than for conventional power plants. Moreover, water can be stored in the shelter and sewage can be ejected on an improvised basis, so that interruption of these services need not be a serious inconvenience.

By contrast, loss of power is a critical problem since in a large basement shelter it means loss of ventilation. Standby sources of light and of heat for cooking can be provided, but manual operation of air handling units is not usually practicable in an apartment or office building basement shelter.

Standby batteries are not regarded as a practical source of emergency power for apartment or office building shelters because of their bulk, relatively short service life, and their basic incompatibility with the electrical characteristics of the normal lighting and mechanical loads.

If normal power is likely to be interrupted, a stand-by engine generator should be provided of an adequate size and with sufficient storage of fuel to maintain at least ventilation and minimal lighting over a two-week period. It may also be economically feasible to operate pumps, sewage ejector, and similar first priority equipment from this generator.

It is extremely important that fuel storage is located in an area protected from thermal effects in order to eliminate the possibility of ignition. Supply lines also should be protected from possible severance by ground shock or structural debris.

Although the National Electric Code calls for automatic load transfer devices where emergency power is supplied, because of the high cost of this equipment and the special character of the shelter emergency, manual double throw switches are considered adequate and appropriate for this purpose. Battery pack lanterns should be provided in critical areas, of the type which lights automatically when the normal power source fails.

To avoid generator overload, circuits can be arranged so that, after a power failure, all large motors connected to the emergency power source must be restarted manually and individually. In some cases, reduced voltage starting devices or special motor types should be considered, to reduce starting loads on the generator.

Gasoline engine-generators are available in the smaller sizes. Since gasoline cannot be stored more than about a year without deterioration, it should be used and replaced on a regular schedule. Alternatively, the carburetor should be designed to accept liquified petroleum gas or natural gas. In some localities the pressurized storage tanks used for liquefied petroleum gas are required to be installed above grade.

Diesel engine generators are rugged and reliable, but are more expensive than gasoline units in the smaller sizes and are harder to start. Diesel fuels of the straight run type, such as kerosene, can be stored indefinitely. Heavier types, however, may settle after a time.

Engines should be water-cooled if a reliable water supply is available. If water is in short supply, it may be advantageous to use remote radiators (outside the shelter) and locate the generator inside the protected area where it can be serviced and maintained.

5-2 Extreme Climates

Heating will seldom be a major problem in a shelter, since crowded human beings ordinarily will generate more than enough heat to maintain environmental temperature at 50 degrees F., which is considered acceptable for warmly-clothed people in good health. Basement shelters will ordinarily be at a comfortable temperature at the beginning of the emergency period. In extremely cold climates it may be advisable either to continue operation of the normal heating system or to provide an emergency heat source. Open flame heat sources should not be used, because of the fire hazard, the oxygen depletion and the build-up in carbon dioxide which they will create within the shelter. Electrical resistance heating or heat recovered from the cooling system of an engine generator may be used instead.

In hot weather the rise in temperature and humidity due to human metabolism can often be kept within acceptable limits (85 degrees F. effective temperature) by taking advantage of the conductive cooling effect of the surrounding earth or by increasing the rate of ventilation with outside air.

The adequacy of earth conduction for limiting the temperature rise in underground shelters during hot weather depends upon many factors, including the following:

1. Aggregate area per person of wall, floor and ceiling surfaces.

2. Thickness of overhead cover.

3. Thermal properties (density, specific heat, conductivity, and moisture content) and initial temperature of the surrounding earth, concrete and other construction materials.

4. Quantity, temperature and humidity of the ventilating air.

5. Physical activity and metabolic characteristics of the occupants.

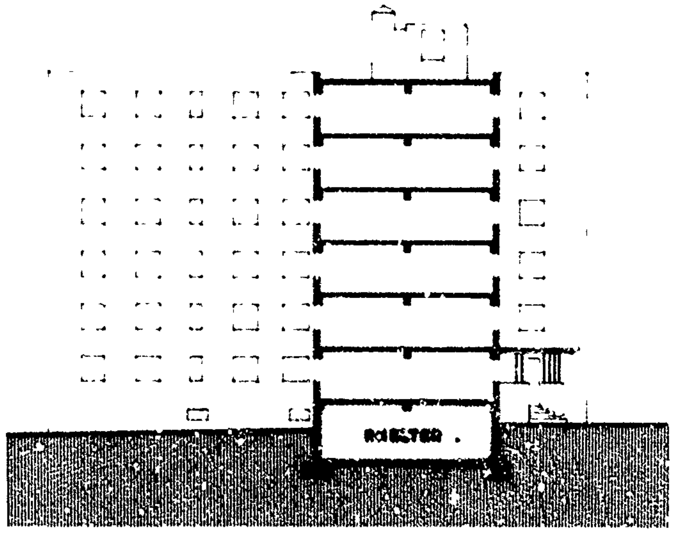
6. Presence of other heat sources.

7. Configuration (size and shape) of the shelter.

A relatively large surface area per person is characteristic of most small shelters and of large shelters having a narrow elongated shape, such as shelters in tunnels. Data from several tests indicate that in most localities the cooling effect of the surrounding earth is sufficient to maintain an acceptable thermal environment in small shelters during an occupancy period of two weeks assuming that the soil is neither unusually dry, light nor initially warm.

In the case of a large shelter which does not have mechanical cooling and dehumidifying equipment and relies upon earth conduction, the ventilating system should be designed to supply large quantities of outside air to the occupied spaces during hot weather and to reduce the supply to a minimum during cold weather. Drafts and stagnant areas can be avoided through the use of a simple system of distribution ducts and diffusion outlets.

Where outside effective temperatures exceeding 85 degrees F. are expected, the air supply may have to be cooled and dehumidified. This can be done inexpensively by passing the air through coils cooled with well water, if an adequate well can be developed on the site. Under circumstances requiring air cooling and dehumidification, about 15 CFM per person of conditioned air should be supplied to the shelter, of which at least 3 CFM should be outside air.



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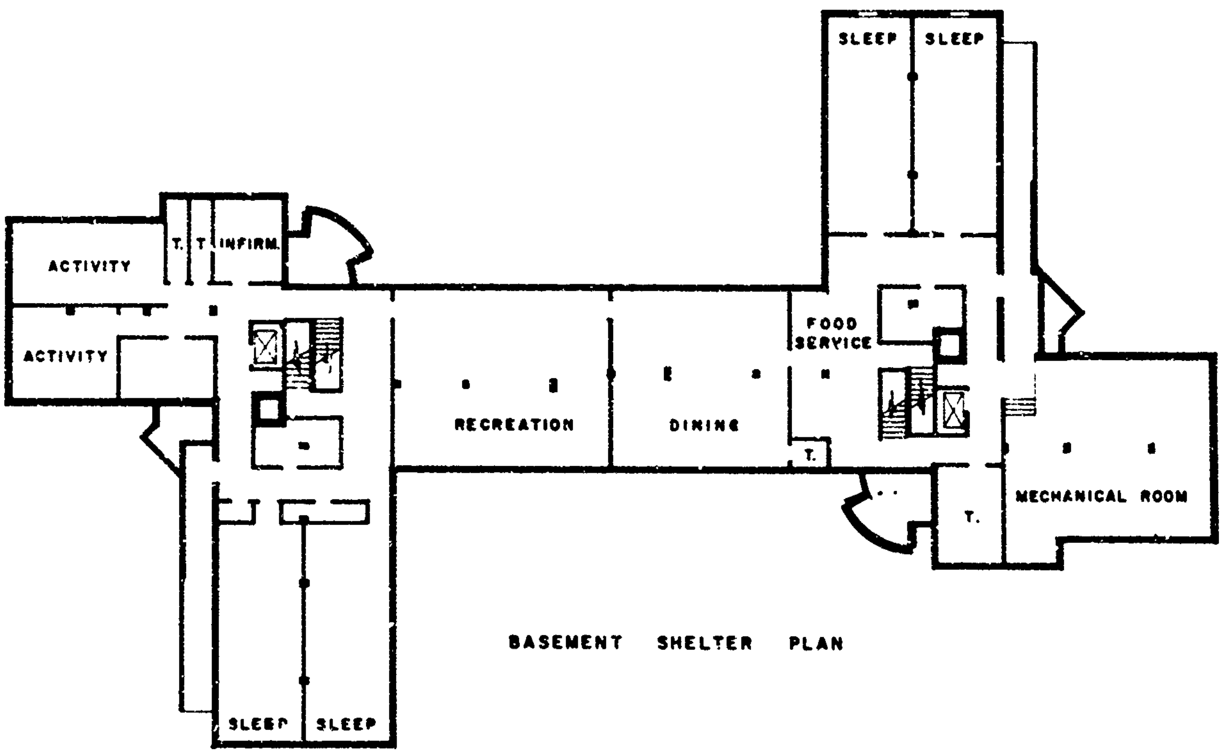
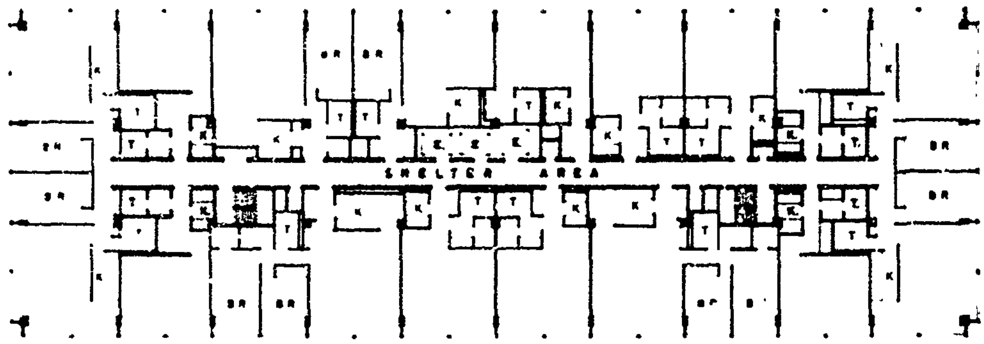
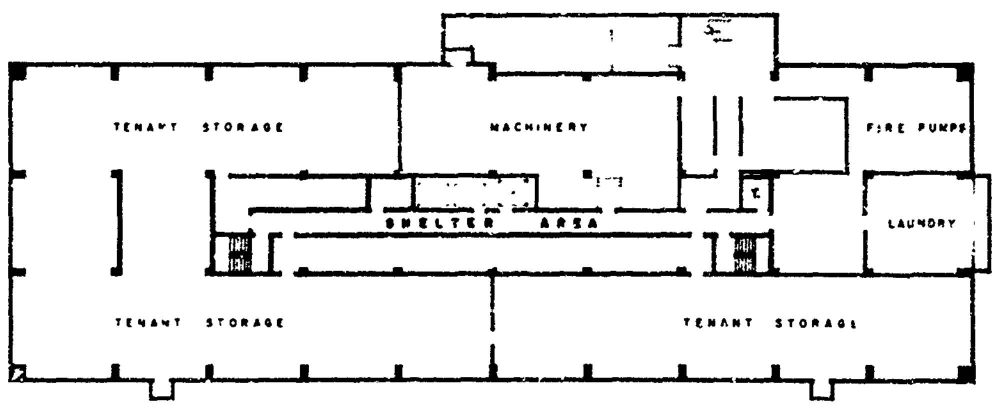


BASEMENT SHELTER PLAN

TYPICAL APARTMENT BUILDING

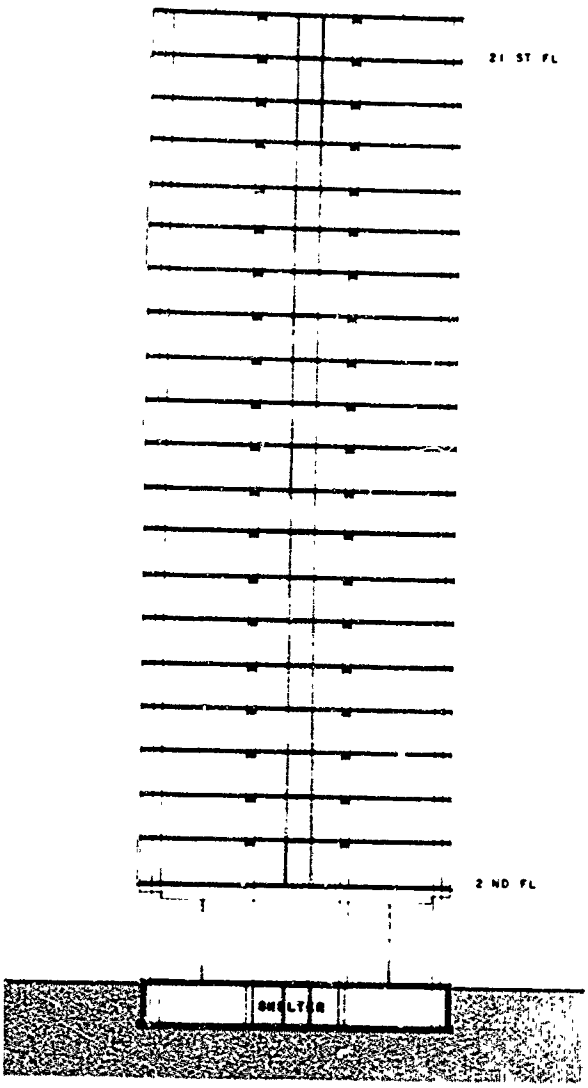


TYPICAL FLOOR PLAN



BASEMENT PLAN

22 STORY APARTMENT



T Y P I C A L   S E C T I O N

B U I L D I N G

CHAPTER VI

DESIGN EXAMPLES

6-1 Typical Apartment Building

The basement of this six story apartment building is planned for laundry, mechanical space and tenant storage. In an emergency it will provide shelter with a protection factor of 350 or better for 380 persons. The peak normal building population is about 300.

The building makes use of concrete skeleton construction and brick masonry exterior walls. Because of the slender plan and the minimal corridor area there is scarcely any useful shelter area on the upper floors. The basement has been converted into shelter by blocking up windows and providing mechanical ventilation.

In emergencies water is available from normal storage and from a well and pressure tank. Sewage ejectors are provided in the basement. A 50 KW engine-generator furnishes emergency power.

Total cost for the shelter in addition to the construction cost of the building is estimated at $39,100 of which $9,100 is for the engine generator, its fuel supply and related equipment. This amounts to a total shelter construction cost of about $103.00 per person and an increase in building construction cost of about $0.61 per square foot.

6-2 Twenty-two Story Apartment Building

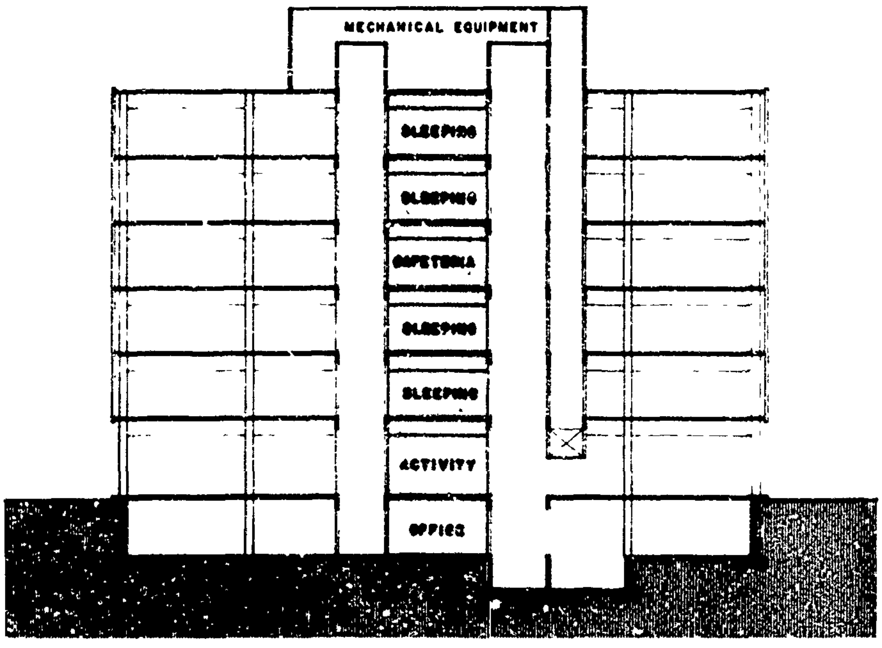
The basement of this 22 story apartment building will provide shelter with a protection factor of better than 5000 for 120 persons and with a protection factor of better than 200 for an additional 390.

The top floor is used to house mechanical equipment and the ground floor is used for lobby and circulation space. The corridors of intermediate floors provide shelter with a protection factor of 100 or better for as many as 2500 additional persons. Peak normal building occupancy is about 700.

The building makes use of exterior curtain walls and steel skeleton framing, and is completely air-conditioned by an absorption unit in the penthouse and a cooling tower on the roof. District steam is provided for heating.

The fresh air intakes are provided with baffles and filters to exclude fallout particles and are planned to permit future installation of chemical and biological filters.

Water for emergency utility and sanitary purposes is available from a well and pressure tank. Normal cold water storage is adequate for emergency



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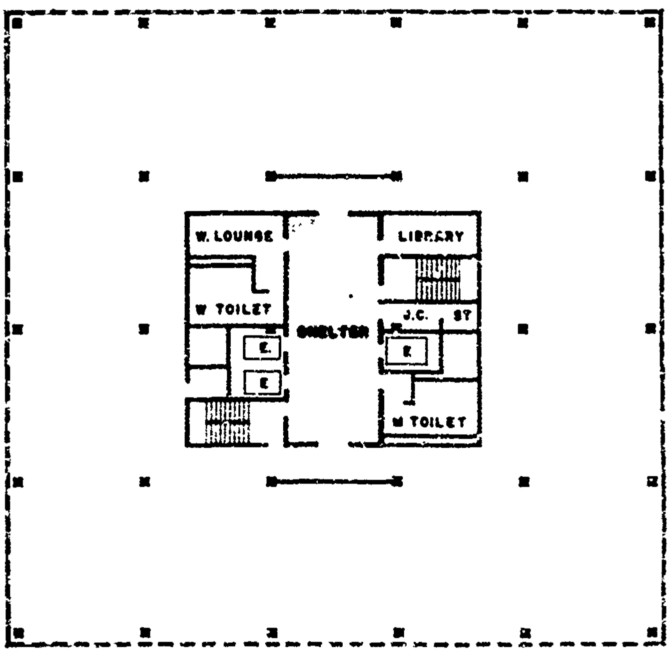
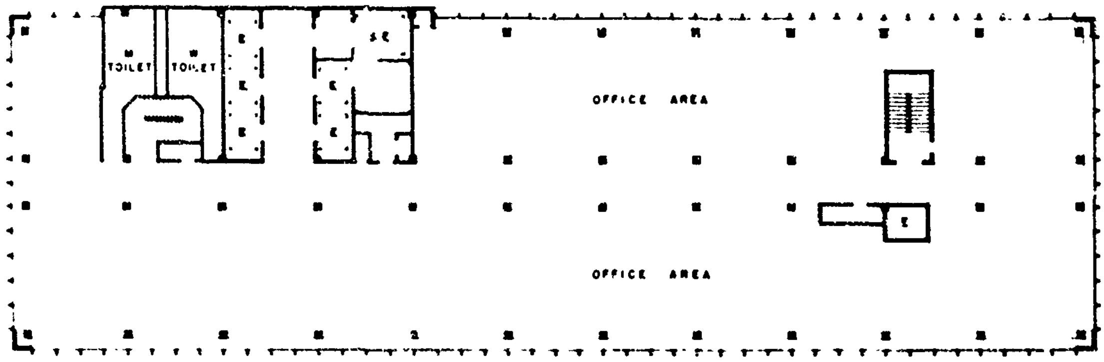
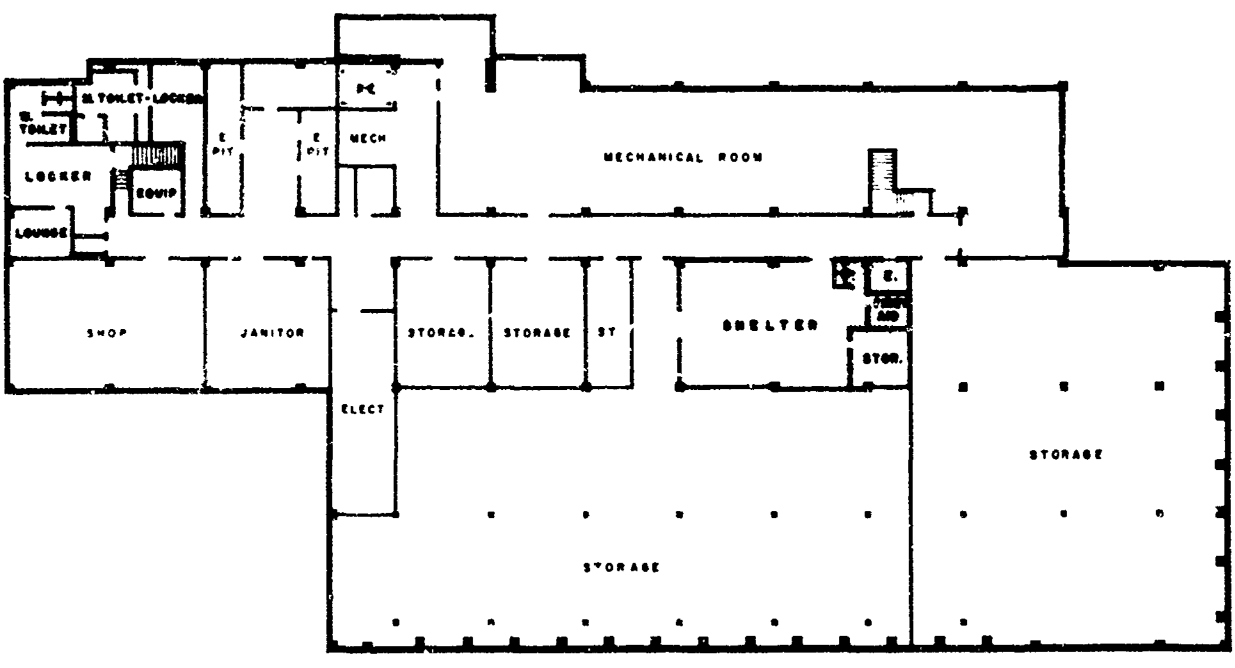


TYPICAL FLOOR PLAN

TYPICAL OFFICE BUILDING

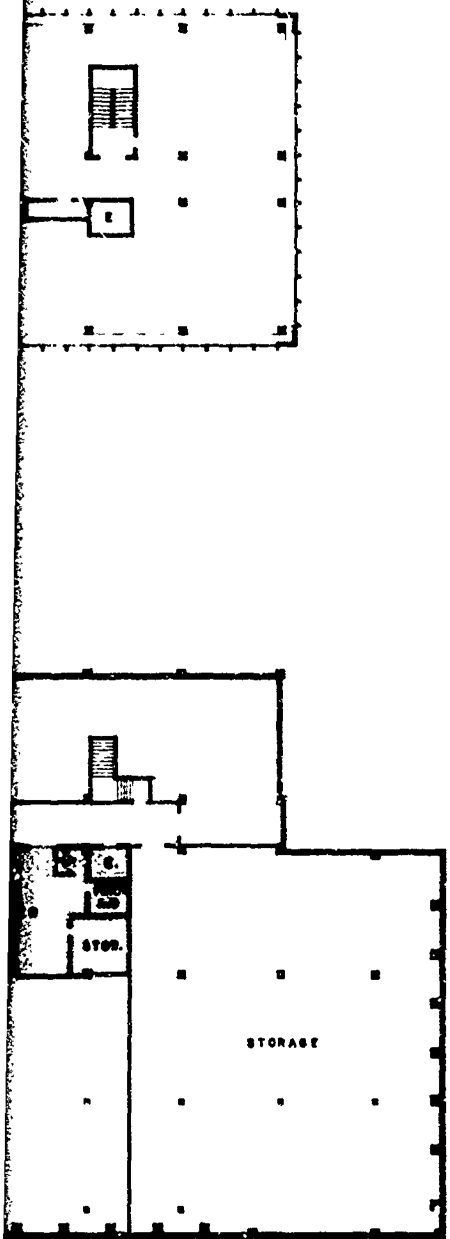


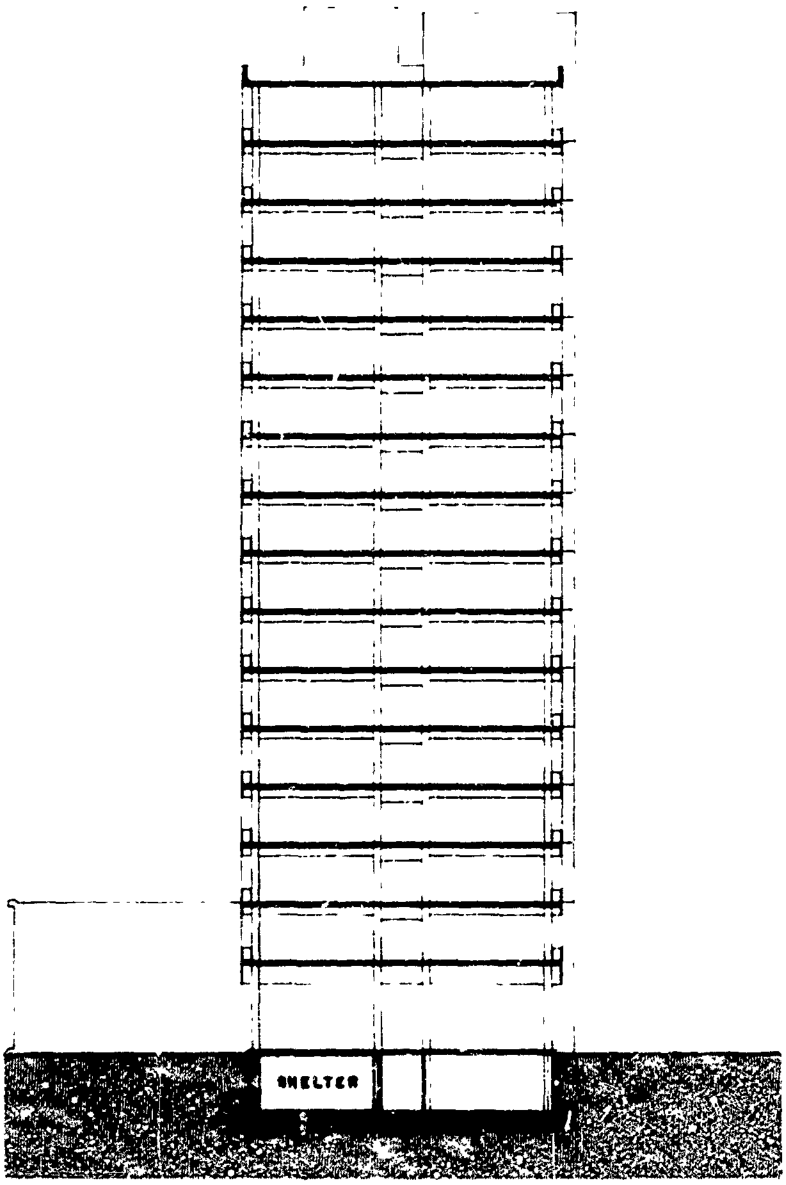
TYPICAL FLOOR



BASEMENT PLAN

STATE OFFICE BUILDING - PITTSBUR





TYPICAL SECTION

BUILDING - PITTSBURGH PENNSYLVANIA

drinking water. Sewage ejectors are provided in the basement shelter. A 375 KW engine-generator furnishes emergency power. Water from the radiator of the engine-generator may be used as a source of emergency heat.

Total cost for shelter over and above the normal construction cost of the building is estimated at $125,370 of which $50,700 is the cost of the engine-generator, fuel storage and related equipment. This amounts to a total shelter construction cost of about $41.70 per occupant, and increase in building construction cost of about $0.42 per square foot.

6-3 Typical Office Building

The basement of this six-story office building is planned for light storage and has sufficient area to provide shelter with a protection factor of 1000 or better for 530 persons. Core areas of the upper floors can provide shelter with a protection factor of 100 for an additional 450 persons. The normal building population ordinarily would not exceed 500.

The building makes use of exterior curtain walls and steel skeleton framing, and is completely air-conditioned by means of absorption units located in the basement and a cooling tower located on the roof. District steam is supplied for heating.

The fresh air intake is provided with baffles and a filter to exclude fallout particles and is planned to permit future installation of chemical and biological filters.

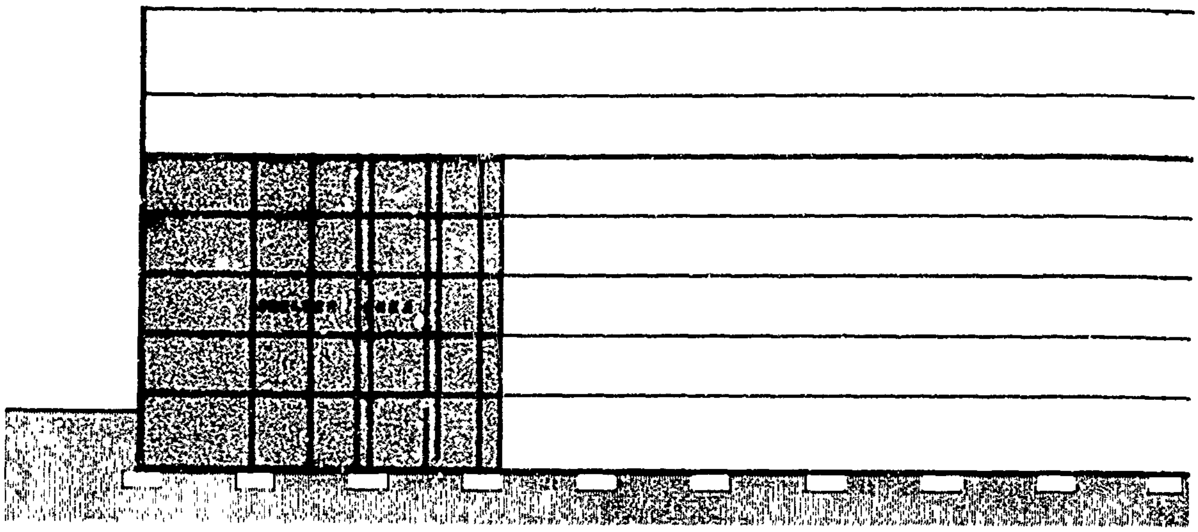
Water for emergency use is available from a well and pressure tank. Sewage ejectors are provided in the basement. A 200 KW engine-generator furnishes emergency power. Water from the radiator of the engine-generator may be used as a source of emergency heat.

Total cost for the shelter over and above the normal construction cost of the building is estimated at $70,770 of which $29,543 is for the engine-generator, its fuel tank and other related equipment. This amounts to a total shelter cost of about $72.30 per occupant and an increase in building construction cost of about $0.71 per square foot.

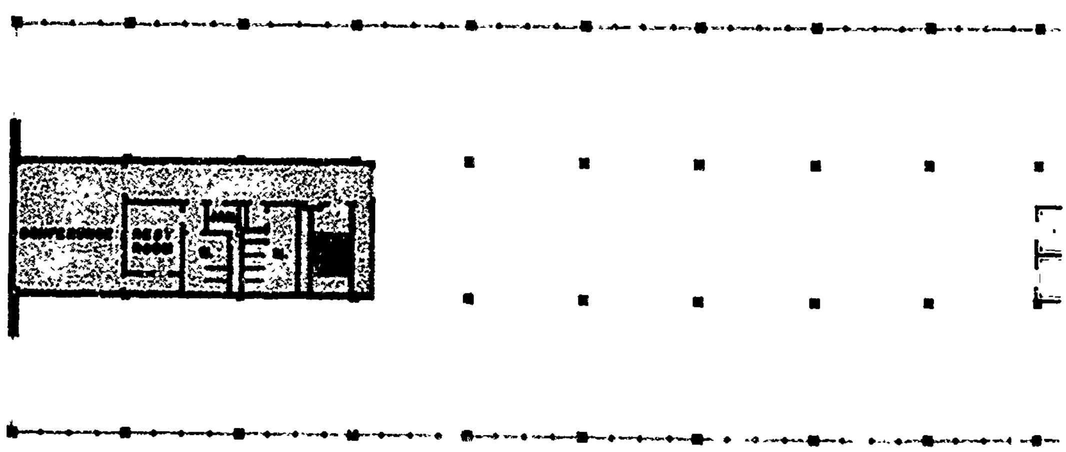
6-4 State Office Building, Pittsburgh, Pennsylvania

Part of the basement of this existing 16-story building has been adapted in accordance with a design developed by the General Services Administration to provide mechanically ventilated shelter with a protection factor of 1000 or better for 150 persons at 8 sq. ft. of net area per occupant. The remaining areas of the basement are not mechanically ventilated, but are capable, with moderate infiltration of fresh air, of sheltering an additional 460 persons with a protection factor of 250 or better. It is estimated that an additional 640 persons can be sheltered in the corridors of floors 4 through 14. Since the normal building population is about 1300 persons, it is apparent that all of them can be sheltered with a very moderate degree of crowding.

In emergencies, water is available from normal storage and from a well and pressure tank. A kitchen sink and a waste water ejector are provided in the primary basement shelter area. Normal use toilets in the



TYPICAL SECTI



TYPICAL FLOOR

NEW YORK STATE OFFICE BUILDIN

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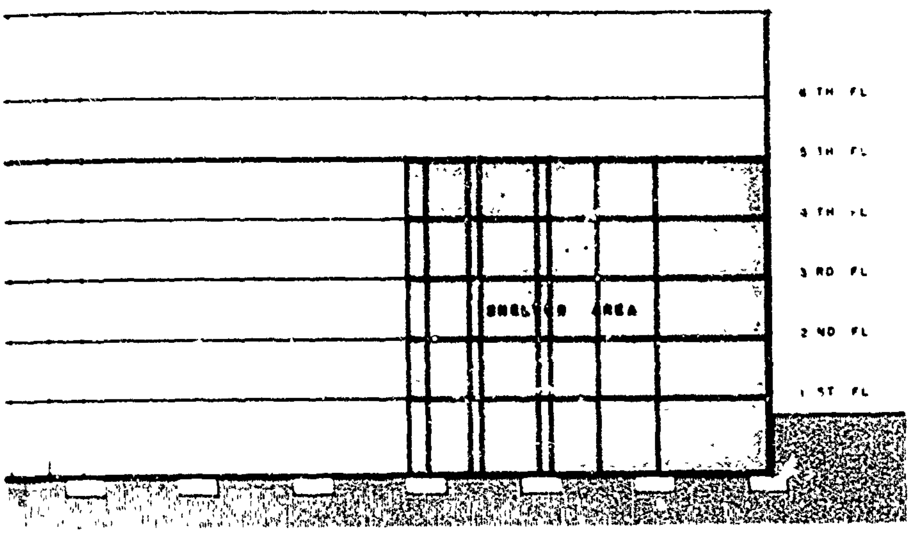

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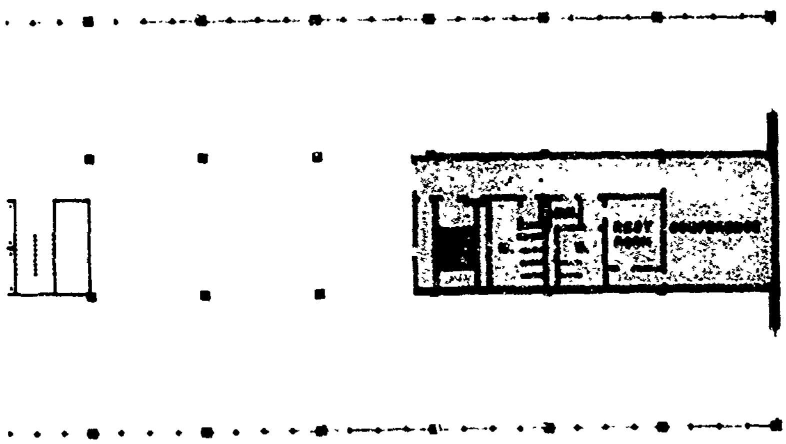


PLAN

G - ALBANY, NEW YORK

basement locker area are supplemented by two chemical toilets in the primary shelter.

If normal electric service is interrupted, manual transfer switches may be used to shift shelter lighting, ventilating and other essential loads to a 25 KW gasoline engine-generator located in the basement. Exhaust air from the primary shelter area is used to cool the engine.

The fresh air intake is provided with a settling chamber and a filter to eliminate fallout particles. Radiation shielding is provided between the filter room and the shelter area, and there is adequate space for future installation of chemical and biological filters.

There is no extra ventilation or special provision for shelter in corridors of upper floors. Food, water and other emergency supplies for these areas can be stored in the basement shelter.

The cost of the additions and alterations to provide shelter in this building are estimated at $22,500 or about $18.00 per occupant.

6-5 State Office Building, Albany, New York

Shelter with a protection factor of 100 or better for 1400 persons has been provided in core areas at each end of the ground floor and of floors 1 through 4 of this 6 story building. The fifth and sixth floor are not used for shelter because of their proximity to fallout on the roof. Initially, there would be only 9 square feet of net area per shelter occupant, but with normal decay of radioactivity it will be possible for persons in the shelter to disperse into adjacent areas of the building after a few days and pass the rest of the shelter period more comfortably.

The building is steel skeleton construction with exterior curtain walls of glass. The core areas at each end each contain fire stairs, men's and women's toilet rooms and a conference room. Core areas are shielded by 12-inch concrete block walls which are solid on the second, first and ground floors, and hollow elsewhere.

In emergencies, water under pressure is available from an elevated storage tank nearby on the site. Conventional sanitary facilities have been supplemented with disposable toilets. One 40 KW diesel generator with a two-week supply of fuel was placed in each end of the building. The normal ventilation system of the building is adequate and available for shelter use, and is capable of maintaining a slight positive pressure inside the shelter.

Total cost for the shelter in addition to the construction cost of the building is estimated at $42,000, or $30.00 per occupant.

APPENDIX A

EFFECTS OF NUCLEAR WEAPONS

The material presented herein is of an introductory nature intended to identify and dimension nuclear weapons effects. More complete information may be obtained from "The Effects of Nuclear Weapons," U. S. Government Printing Office, Washington 25, D. C. and Professional Manuals of the Office of Civil Defense Technical Publications Program.

This material is further restricted to low level blast and accompanying levels of initial nuclear and thermal radiation, and to the residual nuclear radiation associated with fallout.

General

All types of explosions - industrial, conventional high explosive weapons, and nuclear weapons - release a tremendous amount of energy within a relatively confined space over a very short interval of time. This energy release is largely in the form of heat energy; a portion appearing as a flash of light and a heat wave, and a portion coverting the explosion products into gases at extremely high temperatures. Inasmuch as these gaseous products are initially confined within a small volume, tremendous pressures exist. As the hot gases expand, a shock wave is developed which propagates outwards from the center of the explosion. This shock wave, or blast wave as it is more usually referred to, is very similar to a rapidly moving wall of water. As the wave encounters an object it engulfs the object with a resulting squeezing action and attempts to drag along the object with a resulting racking action.

In addition to the fact that the total energy release of a nuclear explosion is many thousand times that of a conventional high explosive, thus extending by many orders of magnitude the destructive range of the thermal energy and blast wave, the nuclear explosion is accompanied by two entirely unique weapon effects. These are the initial nuclear radiation and the residual nuclear radiation, commonly referred to as fallout radiation. Whereas the effects of conventional weapons are significant only within several hundred feet of the detonation, the tremendously greater energy release and fallout of a nuclear weapon make its effects of significance to several hundred miles. Thus, weapons effects are no longer a point problem, but an area problem.

Because of these fundamental differences - the effects of nuclear weapons acquire special significance in the architectural and engineering planning of all buildings.

Yield of a Nuclear Weapon

he size of a nuclear weapon, referred to as its power or yield, is expressed in terms of the energy that is released by TNT. Therefore, a one-kiloton (1 KT) nuclear weapon releases an amount of energy equivalent to that released by one-thousand (1,000) tons of TNT, whereas a one-megaton (1 MT) nuclear weapon releases energy equivalent to one-million (1,000,000) tons of TNT. Nuclear weapons have been detonated with energy releases ranging from a fraction of a kiloton through the 20 kiloton weapons detonated over Japan in 1946 to multi-megaton weapons detonated in nuclear tests conducted during the past several years. To describe the effects of large and small yield nuclear weapons, a 2 MT and a 100 KT weapon have been selected for illustrative purposes.

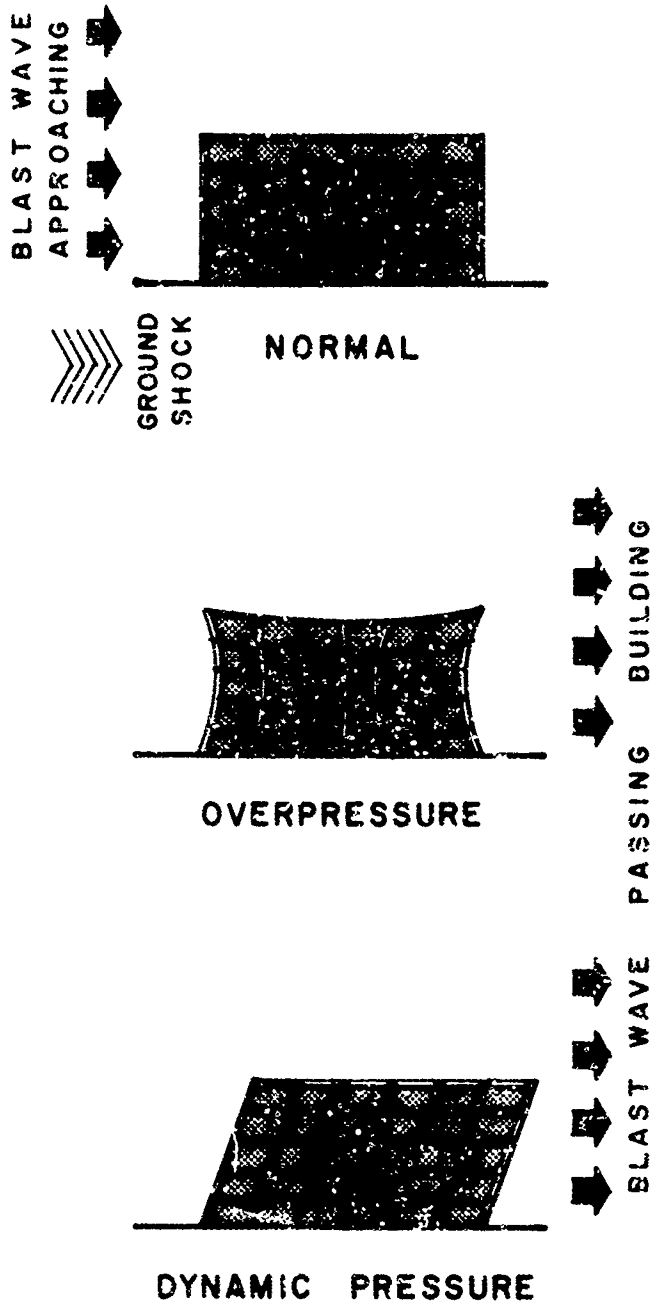
In the explosion of a nuclear weapon, the distribution of energy is determined by both the type of construction of the weapon and the location of the burst (fission, fission-fusion, fission-surface, underground burst). While the fission process maximizes the nuclear radiation effects, the fusion process maximizes the blast and thermal effects. An air burst below 100,000 feet tends to maximize the blast, thermal radiation, and initial nuclear radiation, while minimizing the residual nuclear radiation. A surface burst maximizes the residual nuclear radiation, while minimizing the air blast, thermal radiation, and initial nuclear radiation. An underground burst maximizes the shock effect while little or no thermal or nuclear radiation escapes.

The distribution of energy in a typical air burst of a fission weapon such as was detonated over Japan is as follows: about 85 percent is in the form of heat energy, of which about 50 percent produces blast and shock, and 35 percent appears as thermal radiation (heat and ligh rays); 5 percent constitutes the initial nuclear radiation produced within the first minute after an explosion; and 10 percent is residual nuclear radiation emitted over a very long period.

Blast Effects

In considering the destructive effect of the blast wave, the two most important characteristics are (1) the overpressure, i.e., the excess over atmospheric pressure caused by the compression of the air within the blast wave, and (2) the dynamic pressure, (the wind pressure caused by the motion of the air particles within the blast wave). Most conventional structures will be damaged to some extent when the overpressure in the blast wave is approximately one pound per square inch - the pressure at which glass windows will usually shatter with an occasional window frame failure.

It is pertinent to call attention to the fact that the above pressures and those to be discussed later are all in terms of pounds per square inch (psi), where one psi is equivalent to 144 pounds per square foot (psf).


BLAST WAVE
APPROACHING
GROUND
SHOCK
NORMAL
OVERPRESSURE
PASSING BUILDING
BLAST WAVE
DYNAMIC PRESSURE

Inasmuch as conventional wind load design is for approximately 50 pounds per square foot and design floor loads are on the order of only 80 to 100 pound per square foot, the importance of the pressures encountered in the blast wave of a nuclear explosion is immediately evident.

As the blast wave advances away from the center of explosion, the overpressure at the front steadily decreases due to the increased volume and the pressure behind the shock front falls off. The overpressure, which is caused by the compression of the air within the blast wave, acts equally in all directions and thus tends to compress or squeeze any object engulfed by the blast wave. The dynamic pressure, which is caused by the motion of the air particles within the blast wave, acts in direction of the movement of the blast wave and this tends to push or drag any engulfed object.

The difference in the air pressures outside and inside the building produces a force which can cause damage. After the blast wave has completely engulfed the building, not only will the building walls and roof experience this force, but also the frame of the building will be subjected to a drag force caused by the dynamic pressure. Thus, when the blast wave encounters a building, there is at first a buildup of pressure on the front face. This is followed by a gradual unloading of the front face as the blast wave progresses past the face and sequential loading of the roof, the sides and lastly the back face.

The structural damage sustained by a building will depend on the relationship of the loading to the structural strength and rigidity. This structural strength and rigidity will in turn depend upon the basic structural system, materials of construction, sizing of individual elements, connection details, etc. The blast loading will depend upon the size and location of the nuclear weapon detonation, the building size, shape, and position.

In addition to the structural system of a building, the blast wave can also inflict damage on exposed items such as utility lines and connections to the building and mechanical equipment installed outside the buildings. To prevent damage to people, material, and other items inside a building, it is necessary to provide some positive method of excluding the blast from entering the interior of buildings, or to provide local protection within.

Nuclear Radiation

The nuclear radiations emitted following the detonation of a nuclear weapon are divided into two categories - initial and residual. The initial radiations (those emitted within 1 minute after the explosion) consist of gamma rays and neutrons capable of penetrating large distances in air and producing injurious effects in living organisms. Residual radiations, or fallout (those emitted after 1 minute) consist of alpha and beta particles and gamma rays.

Initial Nuclear Radiation

The initial nuclear radiation problem, like the blast and thermal radiation problems, is a local one, seriously affecting only the area within a few miles of ground zero. For example, the initial nuclear radiations from a 2 MT weapon would probably cause no deaths to individuals beyond two miles from ground zero, affecting an area of perhaps only 12 square miles. In contrast, the residual (fallout) radiations can cause deaths hundreds of miles away, thus affecting areas of over a thousand square miles. The following tabulation lists the effects of initial nuclear radiation on exposed personnel in the open at various distances from 100 KT and 2 MT weapons. These effects decrease rapidly with distance and cause no serious radiation sickness even at 2 miles from a 2 MT weapon.

INITIAL RADIATION EFFECTS ON
EXPOSED PERSONNEL

Effects*	Distance from Burst (Miles) 100 KT	2 MT
LD 100	0.95	1.5
LD 50	1.00	1.6
LD 20 & SD 100	1.05	1.7
LD 0 & SD 50	1.10	1.8
SD 25	1.15	1.9
SD 10	1.20	2.0
SD 0	1.30	2.1

*Effects are expressed in terms of the percentage of the exposed population who would become sick or die. Thus, LD 50 or "Lethal Dose 50," means that 50% of the personnel would die, whereas SD 10 or "Sick Dose 10," that 10% would become sick.

Residual Nuclear Radiation (Fallout)

When a nuclear weapon is detonated on or near the ground so that the fireball contacts the ground, thousands of tons of pulverized and vaporized soil and other materials are carried into the atmosphere in the nuclear cloud. These particles are propelled by a strong updraft and will rise very rapidly to a great height. For example, within eight minutes following a 2 MT surface burst, the cloud may reach its maximum altitude of 70,000 to 80,000 feet. The cloud contains vast quantities of radioactive particles. The particles range in size from visible bits and flakes to submicroscopic particles.

Radioactive fallout is the surface deposition of the radioactive material which has been formed and carried aloft by the nuclear explosion. The particles are then acted upon by two forces - gravity and the winds. The large particles settle to the ground rapidly, the smaller ones more slowly. The rate and place of fall depends on the particle's size, shape, and weight, and the wind speed and direction at various altitudes.

Under normal wind conditions, the heavier material may fall within an hour or two into a roughly circular pattern around ground zero. The lightest particles formed will enter the stratosphere and remain suspended for long periods and probably travel many thousands of miles before descending. The intermediate weight particles will probably reach the earth within a few hundred miles of ground zero. These particles may be expected to form a generally elongated cigar shaped pattern of contamination on the ground.

The radioactive material which is carried in the fallout consists of: (1) fission products which are particles created in the fissioning of the weapon material; (2) particles made radioactive by the neutrons released at the time of the explosion - these particles may have been part of the weapon, casing, weapon tiggering mechanisms, or earth and debris; and (3) the unfissioned uranium or plutonium of the weapon itself.

The unfissioned material generally emits alpha particles, whereas the fission products and the neutron-induced radioactive products are beta and gamma emitters. The alpha radiation may be ignored in the radiation shielding design for protection against fallout since it can be stopped by a thin layer of clothing or the skin itself. The alpha radiation can be a hazard if it enters the body either by ingestion, inhalation or through skin abrasions. However, even this usually may be ignored relative to the ingestion hazard posed by the much more numerous beta and gamma emitters.

Beta particles, which are high energy negative and positive electrons, can be dangerous both internally and externally. The external problem is a relatively trivial one since beta particles are stopped by small thicknesses of solids; their range in wood, water or body tissue being only about a tenth of an inch. Thick clothing will also stop them. They are hazardous, however, when they come in direct contact with the skin or are ingested or inhaled.

Gamma rays, which are high energy electromagnetic radiations like X-rays, are very penetrating and determine completely the amount of material needed for shielding against fallout. Radioactive fallout particles emit gamma rays varying in energy. Even relatively thin shields afford some protection against the rays of lower energy, whereas, adequate protection against the more energetic rays may require considerable mass thicknesses of material.

The basic requirement for protection against fallout is to provide a shield against gamma radiation. Such a shield will protect against the beta radiation as well. The alpha-, beta-, and gamma-emitters must also be excluded from the protected area. This may necessitate both the decontamination of entering personnel and/or the filtration of air.

Beta and gamma rays are emitted by the nuclei of so-called "radioactive" atoms. In the process of emitting these rays a radioactive atom becomes a stable atom, identical with any other atom of its species, and no longer constitutes a hazard. Thus, the intensity of radiation from fallout constantly decreases or decays with time. (See Figure A-1) Radioactive fallout decays by approximately a factor of 10 for every multiple of 7 in time. For example: if the gamma intensity is 5000 roentgens an hour after the burst, its value 7 hours after the burst will be down to 1/10 of 5000 or 500 roentgens; its value 49 hours (approximately 2 days) after the burst will be down to 1/100 of 5000 or 50 roentgens; its value 14 days after the burst will be down to 1/1000 of 5000 or 5 roentgens and so on.

Biological Effects of Nuclear Radiations

In general, the biological effects of exposure to nuclear radiations result from the ionization of and damage to, molecules in the body tissue. The nuclear radiations of primary interest in the problem of protection are the gamma rays.

The basic unit of exposure dose is the roentgen (r). The dose rate, or intensity, measured in roentgens per hour (r/hr), is the time rate at which the radiation dose is delivered.

Some of the effects of nuclear radiations on living organisms depend not only on the total dose, but also on the dose rate. For example, 700 roentgens over the whole body delivered in a short time (less than an hour) would almost inevitably prove fatal to a human. However, if the same dose were delivered over a long period (10 years), at a more or less uniform rate there would probably be no noticeable effects. The reason is, that most of the cells damaged by radiation can be replaced by new cells provided the percentage damaged by radiation is not too high. If recovery cannot keep pace with the damage, injury will result. This explains one of the most characteristic features of radiation injury: the lag that usually occurs between even severe exposure to radiation and the development of pathological symptoms.

Rather large acute radiation doses are not uncommon under ordinary circumstances. For example a flourescent screen examination usually results in a received dose of 4 to 40 roentgens, and X-ray pregnancy examination may result in a dose as high as 70 roentgens. These are not, however, whole body exposures, so that the injury is less severe than the case for nuclear radiation.

Thermal Radiation

Because of the enormous amount of energy liberated in a nuclear weapon, very high temperatures are attained. As a consequence of the high temperatures in the ball of fire, (similar to those in the center of the sun), a considerable portion of the nuclear energy appears as thermal radiation. For every

1 KT of the nuclear explosion, approximately 400,000 kilowatt hours of energy are released as radiant thermal energy within a second of the detonation.

Thermal radiation will contribute to overall damage by igniting combustible materials. In addition, it is capable of causing skin burns on exposed individuals at distances from the explosion where the effects of blast and initial nuclear radiation are not critical. The thermal energy from a specified explosion received by a given surface will be less at greater distances from the explosion for two reasons: (1) the spread of the radiation over an ever-increasing area as it travels away from the fireball, and (2) attenuation of the radiation in its passage through the air. Unless scattered, the thermal radiation from a nuclear explosion travels like light in straight lines from its source - the ball of fire. Any solid, opaque material, such as a wall, a hill, or tree, located between the object and the fireball will thus act as a shield and provide protection from thermal radiation. Transparent materials, on the other hand, such as glass or plastics allow thermal radiation to pass through only slightly reduced in intensity.

The proportion of the energy appearing as thermal radiation will be greater for an air burst than for a surface burst - where the ball of fire actually touches the earth or water. In a sub-surface burst, either in the earth or underwater, nearly all the thermal radiation is absorbed by the earth or water.

The ignition of combustible materials by thermal radiation depends upon a number of factors, the most important are: (1) the nature of the material itself, (2) the thickness and moisture content of the material, (3) the amount of thermal energy falling on a unit area and (4) the intensity of radiation.

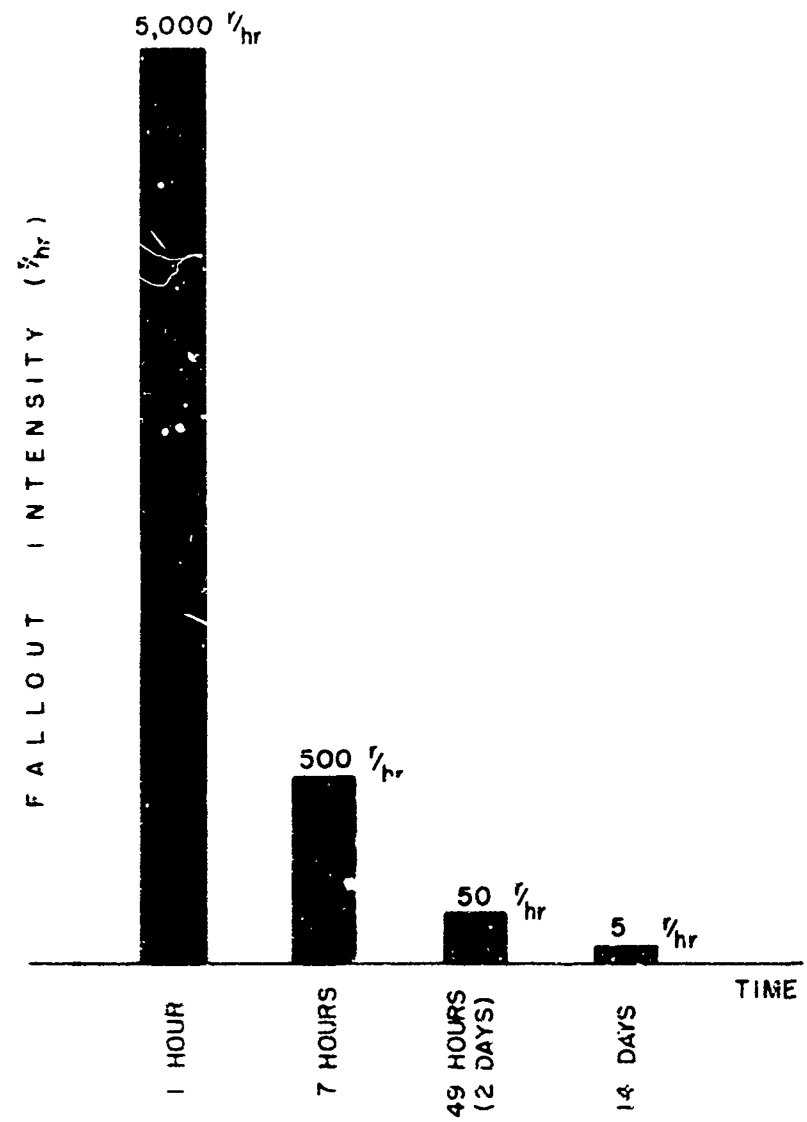


FIGURE A-1

DEPARTMENT OF DEFENSE OFFICE OF CIVIL DEFENSE		
DECREASE OF FALLOUT ACTIVITY WITH TIME		
TM-	OCT.19,1962	DWG.NO.

APPENDIX B

GLOSSARY OF TERMS

Air Burst:	The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface.
Fireball:	The luminous sphere of hot gases which forms a few millionths of a second after a nuclear explosion and immediately starts to expand and cool.
Blast Loading:	The loading (or force) on an object caused by the air blast from an explosion striking and flowing around the object. It is a combination of overpressure and dynamic pressure loading.
Blast Wave:	A pressure pulse of air, accompanied by winds, propagated by an explosion.
Contamination:	The deposit of radioactive material on the earth's surface and other exposed surfaces following a nuclear explosion.
Core:	That portion of a multi-story building assigned to the vertical elements required for distribution of mechanical services and for circulation, such as ductshafts, pipeshafts, elevators and stairwells. It may also contain other spaces which are repeated on each floor, such as toilet rooms and janitor's closets.
Radioactive Decay:	The decrease in activity of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation.
Fission Products:	The complex mixture of substances (about 200 isotopes of more than 30 elements) resulting from nuclear fission.
Flash Burn:	A burn caused by excessive exposure of bare skin to thermal radiation.

Fusion: The process whereby the nuclei of light elements combine to form the nucleus of a heavier element with the release of substantial amounts of energy.

Gamma Rays: Electromagnetic radiations of high energy and great penetrating power originating in the atomic nucleus and accompanying many nuclear reactions.

Initial Nuclear Radiation: Nuclear radiation, primarily neutrons and gamma rays, emitted from the fireball and the cloud column during the first minute after a nuclear explosion.

Net Area: Space usable for human occupancy excluding walls, toilets, storage and mechanical rooms.

Overpressure: The transient increase in pressure in the shock wave of an explosion, usually expressed in pounds per square inch.

Roentgen: A unit of exposure dose of gamma radiation.

Shear Wall: A stiff structural element incorporated as a wall or part of a wall in a building and designed to be capable of resisting horizontal forces such as those due to wind, earthquake and blast.

Shielding: Any material or obstruction which absorbs radiation and protects personnel or materials from the effects of a nuclear explosion.

Shock Wave: A pressure pulse in the surrounding air, earth or water initiated by the expansion of the hot gases produced in an explosion.

Skeleton Framing: A system of construction in which the supporting elements of the building structure form an open framework and in which the exterior and interior walls carry no vertical load other than their own weight.

Surface Burst: The explosion of a nuclear weapon at a height above the surface less than the radius of the fireball.

Thermal Radiation: Electromagnetic radiation emitted from the fireball as a consequence of its very high temperature, consisting essentially of ultraviolet, visible, and infrared radiations.

Yield: The total effective energy (nuclear radiation, thermal radiation and blast) released in a nuclear explosion, usually expressed in terms of the tonnage of TNT required to release equivalent energy in an explosion.

APPENDIX C

REGIONAL OFFICES

OCD Region 1
Oak Hill Road
Harvard, Massachusetts

Connecticut
Maine
Massachusetts
New Hampshire
New Jersey
New York
Rhode Island
Vermont

OCD Region 2
Olney, Maryland

Delaware
District of Columbia
Kentucky
Maryland
Ohio
Pennsylvania
Virginia
West Virginia

OCD Region 3
P. O. Box 108
Thomasville, Georgia

Alabama
Florida
Georgia
Mississippi
North Carolina
South Carolina
Tennessee

OCD Region 4
Battle Creek, Michigan

Illinois
Indiana
Michigan
Minnesota
Wisconsin

OCD Region 5
P. O. Box 2935
University Hill Station
Denton, Texas

Arkansas
Louisiana
New Mexico
Oklahoma
Texas

OCD Region 6
Denver Federal Center
Building 50
Denver 25, Colorado

Colorado
Iowa
Kansas
Missouri
Nebraska
North Dakota
South Dakota
Wyoming

OCD Region 7
Naval Auxiliary Air Station
Santa Rosa, California

Arizona
California
Hawaii
Nevada
Utah

OCD Region 8
Everett, Washington

Alaska
Idaho
Montana
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